PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 1.

JANUARY, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1903.

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American Society of Civil Engineers.

OFFICERS FOR 1903.

President, ALFRED NOBLE.

Vice-Presidents.

Term expires January, 1904:	*Term expires January, 1905:*
CHARLES C. SCHNEIDER,	L. F. G. BOUSCAREN.
JOHN R. FREEMAN.	JAMES D. SCHUYLER.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1904:	*Term expires January, 1905:*	*Term expires January, 1906:*
JOSIAH A. BRIGGS,	RICHARD S. BUCK,	ALFRED CRAVEN,
GEORGE F. SWAIN,	GEORGE H. PEGRAM,	JOSEPH O. OSGOOD,
EMIL KUICHLING,	WILLIAM J. WILGUS,	GEORGE S. DAVISON,
MORDECAI T. ENDICOTT,	WILLIAM JACKSON.	E. C. LEWIS,
EDWARD C. CARTER,	EDMUND F. VAN HOESEN,	HUNTER McDONALD,
FRANK C. OSBORN.	JAMES L. FRAZIER.	ELWOOD MEAD.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOSIAH A. BRIGGS,	GEORGE H. PEGRAM,	CHARLES C. SCHNEIDER.
L. F. G. BOUSCAREN,	ALFRED CRAVEN,	MORDECAI T. ENDICOTT.
GEORGE F. SWAIN,	JOSEPH O. OSGOOD,	EMIL KUICHLING.
RICHARD S. BUCK,	FRANK C. OSBORN,	WILLIAM JACKSON,
WILLIAM J. WILGUS.	GEORGE S. DAVISON.	CHARLES WARREN HUNT.

Special Committees.

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ON RAIL SECTIONS:—G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 533 Columbus.
CABLE ADDRESS, - - - - "Ceas, New York."

Vol. XXIX. JANUARY, 1903. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

January 7th, 1903.—The meeting was called to order at 8.45 P. M., Henry B. Seaman, Director, in the chair; Charles Warren Hunt, Secretary; and present, also, 87 members and 14 guests.

The minutes of the meetings of December 3d and 17th, 1902, were approved as printed in the *Proceedings* for December, 1902.

The discussion on the topic "The Sanitary Disposal of Municipal Refuse" was continued by Messrs. George A. Soper, Theodore Horton, W. J. Baldwin, Charles B. Ball, M. N. Baker, H. de B. Parsons and Rudolph Hering.

Ballots were canvassed and the following candidates declared elected:

As Members.

Thomas Hooker Loomis, Steubenville, Ohio.
William Martin, Bellevue, Pa.
John Colwell Neale, Pittsburg, Pa.

As Associate Members.

Lewis Eugene Ashbaugh, Ames, Iowa.
William Durward Connor, New London, Conn.
William Hastings Ferguson, Denver, Colo.
George Sherman Frost, New York City.
Charles Romney Hall, Portland, Me.
Austin Curtin Harper, Norfolk, Va.
Frederick William Schwiers, New York City.
John Eaton Shepardson, New York City.
Samuel Payson Waldron, East Berlin, Conn.
Ralph Norman Wheeler, New York City.

The Secretary announced the election of the following candidates by the Board of Direction on January 6th, 1903.

As Juniors.

Richard Erwin Dougherty, New York City.
William Dollison Faucette, Savannah, Ga.
Max Feldman, New York City.
Langdon Pearse, Roxbury, Mass.
William Edward Wilson, Detroit, Mich.

Adjourned.

January 21st, 1903.—The minutes of this, the Annual Meeting, will be printed in the *Proceedings* for February, 1903.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 6th, 1903.—8.35 P. M.—Director O'Rourke in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Croes, Jackson, Knap, Pegram, Seaman and Wilgus.

The cases of members in arrears for dues were considered and acted upon.

Upon the recommendation of the Finance Committee, it was decided to pay Ten Thousand Dollars on January 15th, 1903, on account of the principal of the mortgage held by the Mutual Life Insurance Company on the Society House.

A draft of the report to the Board of Direction was presented, by the Special Committee appointed for that purpose, and adopted.

The report of the Committee to recommend the award of prizes for the year ending with the *Transactions*, July, 1902, was received, and the prizes awarded, in accordance with the recommendations of that report, as follows:

The Norman Medal to Paper No. 911, "Experiments at Detroit, Michigan, on the Effect of Curvature upon the Flow of Water in Pipes" by Gardner S. Williams, M. Am. Soc. C. E., Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 910, "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government," by William W. Harts, M. Am. Soc. C. E.

The following resignations were accepted: S. E. Barney, Assoc. M., Frederic V. Pitney, Assoc. M., Henry H. Shepard, Assoc. M., R. C. McKinney, Assoc., Mark Fargusson, Jun., Myron H. Lewis, Jun., George E. Nostrand, Jun., George R. Wadsworth, Jun.

Applications were considered and other routine business transacted.

Five candidates for Junior were elected.*

Adjourned.

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* See page 2.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, February 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and there will be an informal discussion on "The Preservation of Materials of Construction." It is not intended to confine this discussion to any particular material or method, but to invite exchange of opinion, based on experience, of practical methods of securing permanence in engineering structures of all types. Several members have already agreed to take part, and it is hoped that others will come prepared to speak, or will send written communications on the subject.

Wednesday, February 18th, 1903.—8.30 P. M.—At this meeting a paper by George S. Morison, Past-President, Am. Soc. C. E., entitled "The Panama Canal," will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, March 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., entitled "A High-Voltage Power Transmission," will be presented for discussion. This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention of the Society will be held at Asheville, N. C., during the week beginning June 8th, 1903.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1902.

PRESENTED AT THE ANNUAL MEETING, JANUARY 21st, 1903.

The Board of Direction, in compliance with the Constitution of the Society, presents its report for the year ending December 31st, 1902.

MEMBERSHIP.

The changes in membership are shown in the following table:

GRADE.	JAN. 1st, 1902.			JAN. 1st, 1903.			LOSSES.				ADDITIONS.		TOTALS.	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.
Honorary Members	1	9	10	1	8	9	..	..	..	1	....	....	1	....
Corresponding Members	....	2	2	....	2	2	..	..	..	..	....	....	....	....
Members	286	1 222	1 508	312	1 263	1 575	..	1	2	24	*28	§66	27	94
Associate Members	161	451	612	192	522	714	25	5	2	3	†35	‖102	35	137
Associates	38	73	111	43	76	119	2	1	..	3	‡2	12	6	14
Juniors	101	150	251	107	154	261	38	6	14	..	....	68	58	68
Fellows	9	25	34	10	23	33	..	..	..	1	....	....	1	....
Totals	596	1 932	2 528	665	2 048	2 713	65	13	18	32	65	248	128	313

* 25 Associate Members and 3 Juniors.
† 2 Associates and 33 Juniors.
‡ 2 Juniors.
§ 1 Reinstatement.
‖ 1 Reinstatement.

It will be seen that the net increase during the year was 185.

In the report of the Board for 1902, statistics of the yearly growth of the Society for thirty-two years were given, and it was pointed out that the rate of increase for the last few years was apparently not due to temporary conditions. The result of this year seems to emphasize this, the figures of the increase for the past four years being as follows:

1899—Net increase in total membership	103
1900 " " " " "	138
1901 " " " " "	191
1902 " " " " "	185
Total for the past four years	617
Average yearly increase for the past four years	154
Average yearly increase from 1869 to 1898, inclusive	62

The total number of applications received during the year was 362.

Action taken by the Board has been as follows:

Passed to ballot as Members	109
Passed to ballot as Associate Members	140
Elected Associates	14
Elected Juniors	65
Total	328
Applications awaiting action	90

The losses by death reported during the year number 32. They are as follows:

Honorary Member: William Hasell Wilson.

Members: Edward Josiah Blake, Charles Edward Henry Campbell, Lorenzo Russell Clapp, Emilio Del Monte, William Durfee Gelette, Edmund Phillips Hannaford, Charles Fletcher Hillman, Arthur Stanley Hobby, Milton Grosvenor Howe, John Butler Johnson, Moritz Lassig, Charles Hazlehurst Latrobe, William Shattuck Lincoln, George Henry Mendell, James Ellison Mills, Henry Mitchell, Nathaniel Edwards Russell, Ira Alexander Shaler, Martinius Stixrud, Robert Henry Temple, William Van Slooten, Robert Atwell Way, Oscar F. Whitford, Joseph Miller Wilson.

Associate Members: Henry Lawrence Cleverdon, Reginald McKean, Kenneth Oake Plummer Reinholdt.

Associates: John Woodbridge Davis, Charles Edward Hamlin, Peter Milne.

Fellow: Nathaniel Cheney.

LIBRARY.

The accessions to the Library during the year are shown in the following table:

ACCESSIONS DURING THE YEAR 1902.

	Bound Volumes.	Unbound Volumes.	Specifications.	Maps, Photographs and Drawings.	Total.
Donations—					
In answer to special requests	272	1 153	....	1	1 426
From publishers	47	14	....	...	61
Eng. News Pub. Co.	24	148	25	...	197
In regular course	214	1 047	3 070	306	4 637
Exchange of duplicates	322	368	....	...	690
By purchase	237	238	....	...	475
Total	1 116	2 968	3 095	307	7 486

In addition to the above, there have been received 489 duplicates, and 234 separate numbers to complete files of periodicals, neither of which can appear as accessions.

A comparison with the corresponding figures for last year shows that the growth of the Library in 1902 has exceeded that of 1901 (which was regarded as phenomenal) by 1 459 accessions.

The Library now contains:

Bound volumes	11 330
Unbound volumes	27 609
Specifications	5 658
Maps, photographs and drawings	3 000
Total	47 597

The total number of titles in the Library is 19 178.

During the year, 890 volumes have been bound, and 55 bound volumes which were duplicates were received and have replaced previously unbound volumes.

The following amounts have been expended upon the Library during the year:

Purchase of books, 475 volumes	$1 224.87
Express charges, etc	99.90
Binding 890 volumes	931.25
Fixtures and supplies	207.29
Total	$2 463.31

The value of the accessions to the Library during the year is as follows, each accession having been valued separately, as received:

7 011 Donations and exchanges (estimated value)	$2 822.41
475 Volumes purchased (cost)	1 224.87
Binding 890 volumes	931.25
	$4 978.53

Owing to the rapid increase of the Library, and the accession of many new books, by purchase and otherwise, it has been decided to publish a second volume of the classified Catalogue, the first volume of which was published in 1900. This volume is now nearly all in type, and it is expected will be issued to all members in about a month.

For the first 45 years of the life of the Society the total number of accessions to the Library was 30 847, an average yearly addition of 685 volumes. About the close of 1897 the Library was moved into the new House. Since that time the average yearly addition has been 3 350 volumes, the total, as stated above, being now 47 597.

By the terms of the will of the late Herbert Steward, Assoc. Am. Soc. C. E. (who died March 4th, 1899), the Society has received, during

the year, $1 940, and the Board has accepted this bequest under the terms of Mr. Steward's will, which were as follows:

"I give and bequeath to the American Society of Civil Engineers the sum of two thousand dollars, to be known as the Herbert Steward Library Fund. The fund shall be invested and utilized as the Board of Direction of said Society may elect, provided it shall secure a yearly income; which income shall be entirely expended each year for the purchase of books, maps, or apparatus suitable for the Library of said Society, or for the purpose of promulgating engineering information. I also give to said Society such technical books from my library as may be selected by the Secretary of the Society."

A gift of £10 was also received during the year from *Sir* Benjamin Baker, Hon. M. Am. Soc. C. E., for library purposes.

PUBLICATIONS.

During the year the usual ten numbers of *Proceedings* have appeared, and three volumes of *Transactions*, instead of the usual two, have been published.

In the *Proceedings*, the list of references to current engineering literature has covered 51 pages, containing 2 614 classified references to 62 periodicals.

The demand for publications has been much greater than usual, subscriptions and sales during the year amounting to $3 231.16.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 119 850 copies, the actual cost of which to the Society has been $13 904.42.

More than 3 200 volumes of *Transactions* have been bound, during the year, for members and others, in the standard half-morocco or cloth bindings.

SUMMARY OF PUBLICATIONS FOR 1902.

	Number Issued.	Total Edition of Each.	Number of Pages.	Plates.	Cuts.
*Transactions**	3	2 800 2 900 3 100	1 434	52	327
*Proceedings**	10	3 000	1 266	40	141
Constitution and List of Members	1	3 200	237	....	....
Advertisements	10	3 000	108	....	....
Totals	....	.....	3 045	92	468

* Includes Indexes and Tables of Contents.

The cost of publications has been:

For Paper, Printing, Binding, etc., *Transactions* and *Proceedings*		$8 211.14
For Plates and Cuts		957.56
For Boxes, Mailing Lists, Copyright and Sundry Expenses		231.50
For Commission on Advertisements		265.09
For 6 575 copies of Memoirs and Papers		734.61
For List of Members		909.33
Total		$11 309.23
Deduct amount received for advertisements	$1 807.50	
Deduct amount received for sale of publications	3 231.76	
		5 039.26
Net cost of Publications for 1902		$6 269.97

Since publications were begun by the Society, 31 years ago, there have been published 49 volumes of *Transactions*, 28 volumes of *Proceedings* and 33 miscellaneous separate publications, consisting of Indexes, Catalogues, Lists of Members, etc. The total number of pages in these publications has been 42 099, an average yearly output of 1 358 pages.

Beginning with 1896, the system of publication was changed, and since that time *Proceedings* and *Transactions* have been issued separately.

For the 24 years, 1872–1895 (inclusive), there were issued 22 799 pages, a yearly average of 950 pages, and for the past 7 years the total issue has been 19 300 pages, an average of 2 757 pages per year.

MEETINGS.

During the year 25 meetings have been held, as follows: At the Annual Meeting, 2; at the Annual Convention, 6; regular semi-monthly meetings, 17.

At these meetings there were presented 18 formal papers, 4 of which were illustrated with lantern slides; 7 topics for informal discussion, one of which was illustrated with lantern slides; and 8 illustrated lectures.

The Thirty-fourth Annual Convention was held at the Willard Hotel, Washington, D. C. There were registered at this Convention 343 members of the Society, in all grades, accompanied by 377 members of their families, and other guests. This was the most largely attended Convention of the Society ever held.

MEDALS AND PRIZES.

For the year ending with the month of July, 1901, Prizes were awarded, as follows:

The Thomas Fitch Rowland Prize, to L. G. Montony, Assoc. M. Am. Soc. C. E., for his paper entitled "The Ninety-Sixth Street Power Station of the Metropolitan Street Railway Company, of New York City."

The Collingwood Prize for Juniors, to F. A. Kummer, Jun. Am. Soc. C. E., for his paper entitled "A Proposed Method for the Preservation of Timber."

No award of the Normal Medal was made.

FINANCES.

An examination of the Secretary's statement of receipts and disbursements, and of the general balance sheet which accompanies it, will show the financial condition of the Society. During the year the sum of $1 940 has been received from the Executors of the estate of the late Herbert Steward, Assoc. Am. Soc. C. E., this sum to be invested and the yearly proceeds to be used in the purchase of books, maps, or apparatus suitable for the library, or for the purpose of promulgating engineering information.

When, in 1895, the project for building a new house was under consideration, the total assets of the Society (omitting the estimated value of the Library, and of publications in stock) were about $65 000. Making no allowance for increase in the value of the present property since it was purchased, the total assets now are about $167 000.

In the report of the Board for the year 1898, it is stated that "the permanent loan has been fixed at $85 000, which loan has been secured at a rate of 4½ per cent." The payment, on January 15th, 1903, of $10 000 on the principal of the mortgage, which has been authorized by the Board, will reduce the debt to $55 000, which is now carried at 4% interest. In other words, $30 000 has been paid off in four years.

The reports of the Secretary and the Treasurer are appended.

By order of the Board of Direction,

CHAS. WARREN HUNT,
Secretary.

New York, January 6th, 1903.

GENERAL BALANCE SHEET, DECEMBER 31st, 1902.

ACCOMPANYING REPORT OF THE SECRETARY.

ASSETS.		
Building and Lot (cost)		$191 730.26
Furniture (cost)		15 664.30
Publications on hand; inventoried value		13 904.42
Library:		
Cash expended for Books, etc.	$7 824.88	
Estimated Value of Donations	40 600.73	48 425.61
Due from Members	$3 456.26	
" " Non-Members, for Publications	244.81	
" for Advertising	555.00	
		4 256.07
Cash		26 297 39
		$300 278.05

LIABILITIES.	
Dues for 1903, paid in advance	$12 127.23
Mortgage Debt	65 000.00
Funds invested in Society House and Lot, and Library	223 150.82
	$300 278.05

NEW YORK, 19th January, 1903.—We have examined the books and accounts of the American Society of Civil Engineers, and certify that the foregoing Balance Sheet is in accordance therewith, as of 31st December, 1902; and, in our opinion, correctly states the condition of the Society's affairs as shewn by the books at that date.

MENZIES, ROBERTSON & Co.,
Chartered Accountants.

REPORT OF THE SECRETARY, FOR THE

To the Board of Direction of the

Gentlemen,—I have the honor to present a statement of Re-
December 31st, 1902. There is also presented a general balance sheet
New York, January 6th, 1903.

Receipts.

Balance on hand December 31st, 1902, in Bank and Trust Company and in hands of the Treasurer		$15 993.31
Entrance Fees	$6 025.00	
Current Dues	30 786.47	
Past Dues	1 256.88	
Advance dues	12 127.23	
Certificates of Membership	197.47	
Badges	1 213.00	
Sales of Publications	3 231.76	
Advertisements	1 807.50	
Interest	307.35	
Compounding Dues	250.00	
Library	50.75	
Annual Meeting	223.00	
Binding	2 896.87	
Miscellaneous	156.57	
Herbert Steward Library Fund	1 940.00	
Caretaking	28.00	
		62 497.85
		$78 491.16

ceipts and Disbursements for the fiscal year of the Society, ending showing the condition of the affairs of the Society.

Respectfully submitted,

CHAS. WARREN HUNT,
Secretary.

DISBURSEMENTS.

Salaries of Officers	$8 199.97	
Clerical Help	8 759.34	
Caretaking	1 852.23	
Publications	11 044.14	
Postage	3 354.08	
General Printing and Stationery	1 747.84	
Badges	975.20	
Certificates of Membership	117.80	
Binding	2 033.11	
Library	2 459.56	
Maintenance of House	334.71	
Heat, Light and Water	1 068.79	
Betterments	29.48	
Furniture	360.34	
Annual Meeting	785.30	
Convention	434.50	
Prizes	111.00	
Advertising Commission	265.09	
Interest and Insurance	2 700.00	
Petty Expenses	182.29	
Society House Loan	5 000.00	
Current Business	357.95	
Refunds	21.05	
		$52 193.77
Balance on Hand December 31st, 1902:		
In Union Trust Company	$24 562.41	
In Garfield National Bank	749 98	
In hands of Treasurer	985.00	
		26 297.39
		$78 491.16

REPORT OF THE TREASURER.

In compliance with the provision of the Constitution, the Treasurer presents the following report for the year ending December 31st, 1902:

Balance on hand December 31st, 1901			$15 993.31
Receipts from current sources, January 1st to December 31st, 1902		$60 509.35	
Received from Herbert Steward Library Fund		1 940.00	
Received from Sir Benjamin Baker		48.50	
			62 497.85
Payment on audited vouchers for current business, January 1st to December 31st, 1902		$47 193.77	
Payment on principal of Bond and Mortgage		5 000.00	
Balance on hand December 31st, 1902:			
In Union Trust Company	$24 562.41		
In Garfield National Bank	749.98		
In hands of the Treasurer	985.00	26 297.39	
		$78 491.16	$78 491.16

Respectfully submitted,

JOSEPH M. KNAP,

Treasurer, Am. Soc. C. E.

NEW YORK, January 6th, 1903.

ACCESSIONS TO THE LIBRARY.

From December 10th, 1902, to January 13th, 1903.

DONATIONS.*

THE CIVIL ENGINEER'S POCKET-BOOK.

By John C. Trautwine. Revised by John C. Trautwine, Jr., and John C. Trautwine, 3d. Eighteenth Edition, Morocco, 7 x 4 ins., 1 079 pp., illus. New York, John Wiley & Sons, 1902. $5.00. (Donated by John C. Trautwine, Jr., and John C. Trautwine, 3d.)

The preface states that in preparation for the eighteenth edition, this book, the first edition of which appeared thirty years ago, has undergone a far more extensive revision than at any other time. More than 370 pages of new matter have been added, and the new edition is larger, by about 100 pages, than its recent predecessors. The articles on arithmetic are considerably extended by the addition of new matter relating to interest, annuities, depreciation, etc. The conversion tables contain the equivalents of both English and metric units, and each of these in terms of the other. The new article on the location of the meridian is much more complete than its predecessors, and a new table of azimuths of Polaris, corresponding to different hour-angles, has been added. Among the important changes in this edition are those in the articles on Statics, on Beams, and on Trusses. These have been almost entirely rewritten and completely modernized. Under Trusses, modern methods of construction are explained, and several modern roofs and bridges are described and illustrated. The Contents are: Mathematics; Natural Phenomena; Mechanics; Force in Rigid Bodies; Strength of Materials; Hydrostatics; Hydraulics; Constructions, etc.; Water Supply; Test and Well Boring; Rock Drills; Traction, Animal Power; Trusses; Suspension Bridges; Rivets and Riveting; Railroads; Materials. There is an index of forty-one pages.

ANCIENT AND MODERN ENGINEERING AND THE ISTHMIAN CANAL.

By William H. Burr, M. Am. Soc. C. E., M. Inst. C. E. Cloth, 9 x 6 ins., 15 + 473 pp., illus. New York, John Wiley & Sons, 1902. $3.50. Postage or Express, 27 cents additional.

This book is the outcome of a course of six lectures delivered at the Cooper Union in the City of New York, in February and March, 1902, under the auspices of Columbia University. These lectures have been expanded for the purposes of publication. The half-tone illustrations, with scarcely an exception, have been prepared from photographs of the actual subjects illustrated. All such illustrations in Parts V and VI, devoted to the Nicaragua and Panama Canal Routes, are made from photographs at the various locations by members of the force of the Isthmian Canal Commission. The parts are: Ancient Civil Engineering Works; Bridges; Water-Works for Cities and Towns; Some Features of Railroad Engineering; The Nicaragua Route for a Ship-Canal; The Panama Route for a Ship-Canal.

A TREATISE ON ROADS AND PAVEMENTS.

By Ira Osborn Baker, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 8 + 655 pp., illus. New York, John Wiley & Sons, 1903. $5.00.

The author states in the preface that the object of this book is to give a discussion, from the point of view of an engineer, of the principles involved in the construction of country roads and city pavements. The attempt has been made to show that the science of road making and maintenance is based upon well-established elementary principles, and that the art depends upon correct reasoning from the principles rather than in attempting to follow rules or methods of construction. In some cases practical experience has not yet determined the best method of procedure, and in these cases the conflicting views with the reasons for each are fully stated. Considerable space has been given to the economics and location of country roads and to the construction and maintenance of earth roads. The remainder of the book, the portion that considers roads having permanently hard surfaces, is based chiefly upon American experience. The Contents are: Part I. Country Roads. Road Economics; Road Location; Earth Roads; Gravel Roads; Broken-Stone Roads; Miscellaneous Roads; Equestrian Roads and Horse-Race Roads. Part II. Street Pavements. Pavement Economics; Street Design; Street Drainage; Curbs and Gutters; Pavement Foundations; Asphalt Pavements; Brick Pavements; Cobble-Stone Pavement; Stone-Block Pavement; Wood-Block Pavements; Comparison of Pavements; Sidewalks; Bicycle Paths and Race Tracks. There is an index of nine pages.

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

POWER DISTRIBUTION FOR ELECTRIC RAILROADS.

By Louis Bell. Third Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 7 + 303 pp., illus. New York, Street Railway Publishing Company, 1900. $2.50.

The preface states that this book is written in the hope that it may be of service to those whose daily work is concerned with the art of transportation, in which electrical traction is to-day so potent a factor. The author has endeavored to set forth the general principles of the distribution of electrical energy to moving motors, to describe the methods which experience has shown to be desirable in such work, and to point out the ways in which these principles and methods can be co-ordinated in every-day practice. For the most part, apparatus is too mutable to describe exhaustively, unless one is writing a history. The reader will therefore find little of such detail. The volume deals with principles and methods, and, consequently, the examples given in the first edition are, save in unimportant details, as typical of current practice in 1900 as they were in 1896. The chapter headings are: Fundamental Principles; The Return Circuit; Direct Feeding Systems; Special Methods of Distribution; Substations; Transmission of Power for Substations; Alternating Motors for Railway Work; Interurban and Cross Country Work; Fast and Heavy Railway Service.

COMBUSTIBLES INDUSTRIELS.

Houille, Pétrole, Lignite, Tourbe, Bois, Charbon de Bois, Agglomérés, Coke. Par Felix Colomer et Charles Lordier. Paper, 10 x 6½ ins., 565 pp., illus. Paris, Vve. Ch. Dunod, 1903. 19 fr. 50.

For each of the above named fuels, one will find in this work information on its physical and chemical properties, its method of preparation, its use in the various furnaces for stationary boilers, locomotives or ships, its conditions of purchase, etc. The Contents are: Houille—Définition et classification de la houille; Essais et analyse de la houille; Sortage de la houille; Lavage de la houille; Définition industrielle et achat de la houille; Emploi de la houille dans les foyers; Foyers spéciaux; Pétrole—Propriétés et analyse du pétrole; Emplois du pétrole; Brûleurs à pétrole; Lignite, Tourbe, Bois, Charbon de Bois; Agglomérés—Généralités sur les agglomérés; Outillage des usines à agglomérés; Appareils de compression; Coke—Définition et emploi du coke; Théorie de la carbonisation; Fours à coke; Récupération des sous-produits; Installation et prix de revient d'une usine de carbonisation. There is an index of thirty-five pages.

A TEXT-BOOK ON FIELD ASTRONOMY FOR ENGINEERS.

By George C. Comstock. Cloth, 9 x 6 ins., 10 + 202 pp., illus. New York, John Wiley & Son, 1902. $2.50.

The author states in the preface that the present work is not designed for professional students of astronomy, but for another and larger class, found in technical colleges. For many years it has been the author's duty to teach to students of engineering the elements of practical astronomy, and the experience thus acquired has gradually produced the unconventional views that find expression in the present text, and which, to the author's mind, are justified by the following considerations: In the engineering curriculum, work in astronomy is a part of the technical and professional training of students who have no purpose to become astronomers. Under these circumstances it seems to be the duty of the instructor to select for presentation those parts of astronomical practice most closely related to the work of the future engineer, and, with reference to the narrow limits of time allotted the subject, to keep in the background many collateral matters that are of primary interest and importance to the student of astronomy as a science. The chapter headings are: Introductory; Co-ordinates; Time; Corrections of Co-ordinates; Rough Determinations; Approximate Determinations; Instruments; Accurate Determinations; The Transit Instrument; Bibliography; Orientation Tables. There is an index of two pages.

METALLURGICAL LABORATORY NOTES.

By Henry M. Howe. Cloth, 9 x 6 ins., 14 + 140 pp., illus. Boston Testing Laboratories, Boston, 1902. $2.50.

The preface states that metallurgical laboratory instruction of the established type reproduces the industrial metallurgical processes, each as a whole, and with such fidelity to actual industrial practice as is attainable. This, which may be called "Applied Metallurgy," seems to the author to have inherent and very grave faults. In its place he has tried to work out a system of what may be called "Theoretical," or better, "Analytical Metallurgy," with the aim of teaching, not individual processes each as a whole, but the individual underlying principles each by itself. This he has tried to do by means of a series of distinct experiments, each testing directly one or more of these principles. With a few exceptions, all the experiments in this work have been carried out either in the metallurgical laboratory of the School of Mines of Columbia University, or earlier in the author's private laboratory, and either exactly in the form here given, or in a form of which the present is a slight modification. The tables at the end of the work are original here, except that of atomic weights, and also, except in a sense, that of melting points of silicates. The book is divided into the following groups: Squad Experiments

and Others for a Short Course in Metallurgy; Pyrometry and Calorimetry; Melting Points of Silicates, etc.; Properties of Refractory Materials; Iron and Steel; Non-Ferrous Metals. There is an index of ten pages.

THE PHYSICAL GEOGRAPHY OF NEW YORK STATE.

By Ralph S. Tarr. (With a Chapter on Climate by E. T. Turner.) Cloth, 9 x 6 ins., 13 + 397 pp., illus. New York, The Macmillan Company, 1902. $3.50 net.

It is stated in the preface that at the request of the American Geographical Society in 1896 a series of articles on the Physical Geography of New York State was undertaken and the first number appeared in the Bulletin of the American Geographical Society, Vol. XXVIII, 1896. When these articles were begun, it was the author's intention to cover the subject in two or three numbers; but, after getting well into the task, it became evident that to cover the field with any fulness would require many more chapters than were originally planned, and, therefore, the series lengthened out to twelve numbers and was not finished until 1900. In the main, this book is a reprint of the articles as published in the Bulletin, but there has necessarily been a certain amount of revision, and many of the more important papers on the subject which have appeared since the original publication of the articles have been made use of, so that the bibliography has been brought down to date. The chapter headings are: General Physical Features; The Mountains of the State; Plains and Plateaus; The Influence of the Glacial Period upon Topography; The Rivers of New York; Lakes and Swamps; Origin of the Basins of the Great Lakes; Post-Glacial History of the Great Lakes; Niagara; The Shore Lines; The Climate of New York; Influence of Physiographic Features upon the Industrial Development of the State. There is an index of eight pages.

EXPÉRIENCES SUR LE TRAVAIL DES MACHINES-OUTILS.

Pour les Métaux. Par C. Codron. Paper, 11 x 9 ins., 2 + 267 pp., illus. Paris, Vve. Ch. Dunod, 1902. 12 fr. 50.

The preface states that while continuing the publication of the study on the work of machine-tools in the *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, the author has thought that it would be advantageous to bring out the first part for the public who are interested in mechanical arts. The Contents are: Meulage; Essais de meulage; Essais à vitesse variable; Tranchage; Tranchage du plomb, du cuivre, du fer, de l'acier; Emploi de deux tranches opposées; Coupe avec deux molettes; Essais de pénétration d'une molette; Coupe des tubes; Cisaillage; Essais de cisaillage à lames parellèles; Cisaillage avec lames obliques; Essais de cisaillage avec lames circulaires; Essais de cisailleuse; Essais de cisaillage à vitesse variable; Poinçonnage; Formes des débouchures; Essais divers de poinçonnage: Poinçons aléseurs à tranchants multiples; Alésage de trous à la broche; Poinçonnage progressif; Essais de poinçonneuse; Essais de poinçonnage multiple; Poinçonnage sur épaisseurs multiples.

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Univ. of Texas Mineral Surv. 1 map.

BY PURCHASE.

Treatise on Wooden Trestle Bridges According to the Present Practice on American Railroads. By Wolcott C. Foster. Third Revised and Enlarged Edition. New York, John Wiley & Sons; London, Chapman & Hall, 1902.

The Practical Application of the Slide Valve and Link Motion to Stationary, Portable, Locomotive, and Marine Engines, with New and Simple Methods for Proportioning the Parts. By William S. Auchincloss, M. Am. Soc. C. E. Fourteenth Edition, Revised. New York, D. Van Nostrand Company, 1901.

Annual Report of the Signal Officer to the Secretary of War, 1871, '73, '74. Washington, Government Printing Office, 1871–74.

Army Meteorological Register for Twelve Years, from 1843 to 1854, Inclusive, Compiled from Observations Made by the Officers of the Medical Department of the Army, at the Military Posts of the United States, Prepared under the Direction of Brevet Brigadier General Thomas Lawson, Surgeon General, United States Army. Washington, A. O. P. Nicholson, 1855.

Topographical Drawing and Sketching, Including Applications of Photography. By Henry A. Reed. Fourth Edition—Revised and Enlarged. 2 vol. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1897.

Building Construction and Superintendence. By F. E. Kidder. Part I, Fifth Edition. Part II, Fourth Edition. New York, William T. Comstock, 1902.

Architects' and Builders' Pocket-Book of Mensuration, Geometry, Geometrical Problems, Trigonometrical Formulas and Tables, Strength and Stability of Foundations, Walls, Buttresses, Piers, Arches, Posts, Ties, Beams, Girders, Trusses, Floors, Roofs, etc. In Addition to which is a Great Amount of Condensed Information: Statistics and Tables Relating to Carpentry, Masonry, Drainage, Painting and Glazing, Plumbing, Plastering, Roofing, Heating and Ventilation, Weights of Materials, Capacity and Dimensions of Noted Churches, Theatres, Domes, Towers, Spires, etc., with a Great Variety of Miscellaneous Information. By Frank E. Kidder. Thirteenth Edition, Revised and Greatly Enlarged. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1902.

SUMMARY OF ACCESSIONS.

From December 10th, 1902, to January 13th, 1903.

Donations (including 61 duplicates and 10 numbers completing volumes of periodicals)	269
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MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(December 10th, 1902 to January 13th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France. Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

The Footbridge for Building the Cables of the New East River Bridge.* Isaac Harby, Jun. Am. Soc. C. E. (54) Vol. xlix.
The Widening of London Bridge.* (12) Serial beginning Dec. 5.
Construction of the Blackwell's Island Bridge Masonry.* (14) Dec. 13.
The Design and Construction of a 50-ft. Brick Arch Culvert across Rock Creek, Washington, D. C.* W. J. Douglas. (13) Dec. 25.
Bridges, Foundations, Docks and Water Fronts, and Canals. William H. Burr, M. Am. Soc. C. E., M. Inst. C. E. (14) Jan. 3.
The Monongahela Bridge.* (14) Jan. 3.
The Mississippi River Bridge at Thebes.* (15) Jan. 9.
Le Pont Monumental de Luxembourg.* Cart. (38) Dec.
Nouvelle Méthode pour le Calcul du Moment de Résistance i/v et du Moment d'Inertie I.* Lathuillière. (36) Dec. 10.

Electrical.

Investigations of Magnetic Fields, with reference to Ore-Concentration.* Walter R. Crane. (56) Vol. xxxi.
Three-Wire System for Variable Speed Motor Work.* N. W. Storer. (42) Dec.
The Storage Battery as a Factor in Speed Control.* H. Blohs. (42) Dec.
Electrically Operated Coal Hoist Having Variable Speed Control.* P. O. Keilholtz. (42) Dec.
A Series-Parallel System of Speed Control.* Geo. W. Fowler. (42) Dec.
Multiple Unit, Voltage Speed Control for Trunk Line Service.* H. Ward Leonard. (42) Dec.
Continuous Current Motors for Machine Tools. F. O. Blackwell. (42) Dec.
The Use of Specification Forms in Designing Dynamo Machinery, and the Design of a Rotary Converter. H. M. Hobart. (26) Serial beginning Dec. 5.
Commutation.* H. St. Hill Mawdsley. (26) Dec. 5.
Experiments on the Application of Pupin's System to Telephone Circuits. F. Dolezalek and A. Ebeling. (26) Serial beginning Dec. 12.
Cleckheaton Electricity Works.* (26) Dec. 12.
Imperial Telegraphic Communication. Charles Bright. (26) Serial beginning Dec. 12.
Some Limits in Heavy Electrical Engineering. James Swinburne. (Presidential address delivered before the Inst. of Elec. Engrs.) (47) Serial beginning Dec. 13; (26) Serial beginning Dec. 12.
Electrochemical Oscillations.* Woolsey McA. Johnson. (27) Dec. 13.
Three-Phase Measurements.* A. S. McAllister. (27) Dec. 13.
The Manufacture and Laying of the Vera Cruz-Frontera-Campeche Cable for the Mexican Government.* (27) Dec. 13.
Photometry for Electricians and Others. (66) Dec. 16.
On Electrons. *Sir* Oliver Lodge. (Paper read before the Inst. Elec. Engrs.) (26) Serial beginning Dec. 19.
A Criticism of Present-Day Continuous-Current Designing. Fred. W. Davies. (26) Dec. 19.
Electric Heating and Lighting in the Carnegie Residence, New York.* (14) Dec. 20.
Ruhmer's Photoelectric Telephone.* A. Frederick Collins. (27) Dec. 20.
A French System of Train Lighting. P. Letheule. (27) Dec. 20.
Electric Furnaces.* Clinton Paul Townsend. (27) Dec. 20.
The New Niagara.* Waldon Fawcett. (62) Dec. 25.
Electricity Supply in Hastings.* (26) Dec. 26.
The Designing of Polyphase Current Machines. David Bergman. (26) Dec. 26.
300-Kilowatt Triple-Expansion Engine; Middlesbrough Electricity Works.* (11) Dec. 26.
Electrically-Driven Quadruplex Two-Stage Compressors, and Their Use for Power in Collieries and Works.* (22) Dec. 26.
The Cauvery Falls Power Plant.* (16) Dec. 27.
The Cost of Electric Light and Electric Light Plants to Municipalities. (60) Jan.
Electric Power in India; the Cauvery Falls Plant.* J. H. Thomson. (10) Jan.
Economy in the Design and Operation of Electric Plants.* Percival Robert Moses. (9) Jan.
Modern Tendencies in the Development and Transmission of Power. John Joseph Flather, M. Am. Soc. M. E. (Abstract of Vice-Presidential address before the Am. Assoc. for the Advancement of Science.) (13) Jan. 1.
The Water and Electric Power System of the Pike's Peak Power Co., Col.* W. P. Hardesty. (13) Jan. 1.
Electrical Distribution of Power in Industrial Establishments. Cecil P. Poole, Member A. I. E. E. (14) Jan. 3.
The First Three-Phase Power Transmission Plant in Europe Operating at 30,000 Volts.* H. Behn-Eschenburg. (27) Jan. 3.
Analysis of Wireless Telegraph Systems in 1902.* A. Frederick Collins. (27) Jan. 3.
The Relation of Synchronous Impedance to the Impedance at Standstill. F. Townsend, H. P. Freund, W. I. Reich. (27) Jan. 3.
Telephone Cables, Cost of Cable Wire Plant. Arthur V. Abbott. (27) Jan. 3.
New Shops of the British Thomson-Houston Company.* (27) Jan. 3.
Three-Phase Measurements. Leslie L. Perry. (27) Jan. 10.
Electrical Supply from Water Power at Portland, Me.* Alton D. Adams. (27) Jan. 10.

* Illustrated.

Electrical—(Continued).

Mesure à l'Aide d'un Seul Wattmètre de la Puissance dans les Circuits Équilibrés, Parcourus par des Courants Triphasés.* Octave Robert. (36) Dec. 10.
Station Centrale Électrique de Waterside à New York.* F. Drouin. (33) Dec. 13.
Fabrication des Lampes Electriques à Incandescence.* Paul Razous. (33) Dec. 20.

Marine.

The Submarine Torpedo Boat, *Protector*.* (12) Dec. 12.
The Application of Turbine Propulsion to Passenger Vessels.* Herbert C. Fyfe. (46) Dec. 13.
The New German Battleship *H*.* (12) Dec. 19.
The New Armored Cruisers *Tennessee* and *Washington*.* (46) Dec. 27.
Developing a British War Post, an Outlay of £4 500 000 (Dockyard Extension).* Archibald S. Hurd. (10) Jan.
A New Departure in British Cruiser Machinery; the Question of Water-Tube Boilers.* George Halliday. (10) Jan.
The New York Shipbuilding Company's Plant, Camden, N. J.* (14) Serial beginning Jan. 3.

Mechanical.

Problems in Hauling and Hoisting. Alexander Bowie. (56) Vol. xxxi.
The D'Auria Air-Compressor.* Henry G. Morris. (56) Vol. xxxi.
Machine Tools. Jas. K. Cullen. (61) Nov. 18.
Some Notes on Several Types of Mantles for Incandescent Gas Burners. William Lincoln Smith. (7) Dec.
The Operation of Machine Shops by Individual Electric Motors. R. T. E. Lozier. (42) Dec.
Modern Handling of Iron Ore on the Great Lakes.* Jas. N. Hatch. (4) Dec.
Foundry Management in the New Century.* Robert Buchanan. (9) Serial beginning Dec.
Flow Through Centrifugal Pumps.* Jas. Alex. Smith. (Paper read before the Victorian Inst. of Engrs.) (11) Dec. 5.
The Brunck System of By-Product Coke Ovens.* (22) Dec. 5.
The Lighting of Factories. J. H. Brearley. (Paper read before the Manchester District Inst. of Gas Engrs.) (66) Dec. 9.
Briquetting Iron Flue Dust. R. M. Hale. (20) Dec. 11.
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Vol. XXIX. JANUARY 1903. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

PROGRESS REPORT OF SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT.

PRESENTED AT THE ANNUAL MEETING, JANUARY 21ST, 1903.

Your Committee on Uniform Tests of Cement has devoted much time, and given very careful consideration, to the subject. Frequent meetings have been held, and a number of investigations carried on, some of which cannot be finally reported at this time.

On several matters which have been considered, such as the substitution of a natural sand for the standard quartz, and the tests for the normal consistency and constancy of volume, the Committee has not reached final conclusions.

While not prepared to submit a final report, the Committee feels that it should present a report of progress in order that the Society may be informed of the results of its investigations and conclusions.

In order to do full justice to the subject under consideration, it will be necessary to compile and report the results of the experiments now under way, and your Committee asks, therefore, that it be continued.

SAMPLING.

1.—*Selection of Sample.*—The selection of the sample for testing is a detail that must be left to the discretion of the engineer; the number and the quantity to be taken from each package will depend largely on the importance of the work, the number of tests to be made and the facilities for making them.

NOTE.—Discussion on this report is requested.

2.—The sample shall be a fair average of the contents of the package; it is recommended that, where conditions permit, one barrel in every ten be sampled.

3.—All samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

4.—*Method of Sampling.*—Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

Chemical Analysis.

5.—*Significance.*—Chemical analysis may render valuable service in the detection of adulteration of cement with considerable amounts of inert material, such as slag or ground limestone. It is of use, also, in determining whether certain constituents, believed to be harmful when in excess of a certain percentage, as magnesia and sulphuric anhydride, are present in inadmissible proportions. While not recommending a definite limit for these impurities, the Committee would suggest that the most recent and reliable evidence appears to indicate that magnesia to the amount of 5%, and sulphuric anhydride to the amount of 1.75%, may safely be considered harmless.

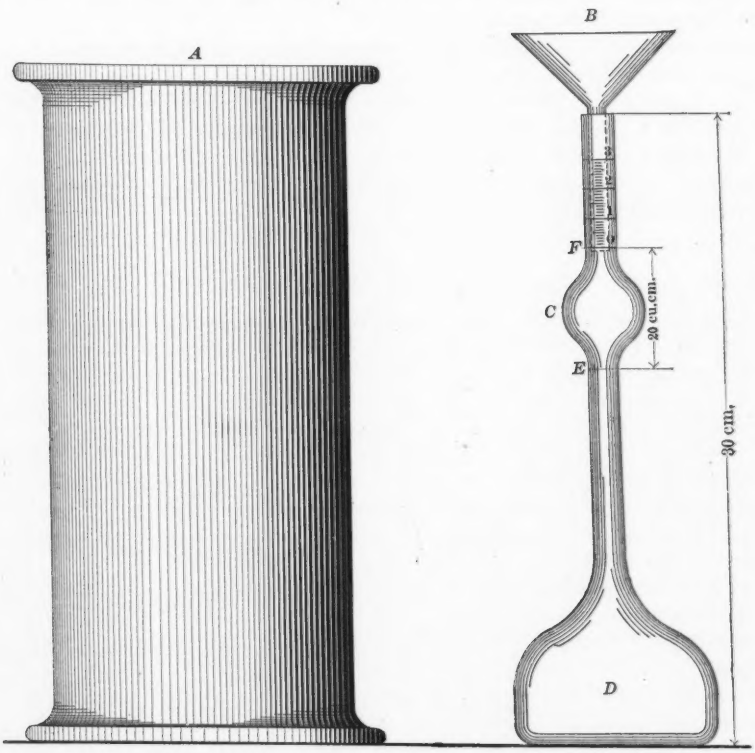
6.—The determination of the principal constituents of cement—silica, alumina, iron oxide and lime—is not conclusive as an indication of quality. Faulty character of cement results more frequently from imperfect preparation of the raw material or defective burning than from incorrect proportions of the constituents. Cement made from very finely-ground material, and thoroughly burned, may contain much more lime than the amount usually present and still be perfectly sound. On the other hand, cements low in lime may, on account of careless preparation of the raw material, be of dangerous character. Further, the ash of the fuel used in burning may so greatly modify the composition of the product as largely to destroy the significance of the results of analysis.

7.—*Method.*—As a method to be followed for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and published in the *Journal* of the Society for January 15th, 1902, is recommended.

Specific Gravity.

8.—*Significance.*—The specific gravity of cement is lowered by underburning, adulteration and hydration, but the adulteration must be in considerable quantity to affect the results appreciably.

9.—Inasmuch as the differences in specific gravity are usually very small, great care must be exercised in making the determination.



LE CHATELIER'S SPECIFIC GRAVITY APPARATUS.

Fig. 1.

10.—When properly made, this test affords a quick check for underburning or adulteration.

11.—*Apparatus and Method.*—The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask (*D*), Fig. 1, of 120 cu. cm. (7.32 cu. ins.) capacity the neck of which is about 20 cm. (7.87 ins.) long; in the middle of this

neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these marks is 20 cu. cm. (1.22 cu. ins.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the bulb.

12.—Benzine (62° Baumé naphtha), or kerosene free from water, should be used in making the determination.

13.—The specific gravity can be determined in two ways:

(1) The flask is filled with either of these liquids to the lower mark (*E*), and 64 gr. (2.25 oz.) of powder, previously dried at 100° Cent. (212° Fahr.) and cooled to the temperature of this liquid, is gradually introduced through the funnel (*B*) [the stem of which extends into the flask to the top of the bulb (*C*)], until the upper mark (*F*) is reached. The difference in weight between the cement remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

14.—(2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

15.—The specific gravity is then obtained from the formula:

$$\text{Specific Gravity} = \frac{\text{Weight of Cement}}{\text{Displaced Volume.}}$$

16.—The flask, during the operation, is kept immersed in water in a jar (*A*), in order to avoid variations in the temperature of the liquid. The results should agree within 0.01.

17.—A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

18.—More accurate determinations may be made with the picnometer.

Fineness.

19.—*Significance.*—It is generally accepted that the coarser particles in cement are practically inert, and it is only the extremely fine powder that possesses adhesive or cementing qualities. The more finely cement is pulverized, all other conditions being the same, the more sand it will carry and produce a mortar of a given strength.

20.—The degree of final pulverization which the cement receives at the place of manufacture is ascertained by measuring the residue retained on certain sieves. Those known as the No. 100 and No. 200 sieves are recommended for this purpose.

21.—*Apparatus.*—The sieves should be circular, about 20 cm. (7.87 ins.) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan, 5 cm. (1.97 ins.) deep, and a cover.

22.—The wire cloth should be woven (not twilled) from brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

23.—This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:

No. 100, 96 to 100 meshes to the linear inch.
No. 200, 188 to 200 " " " "

24.—Fifty grams (1.76 oz.) or 100 gr. (3.52 oz.) should be used for the test, and dried at a temperature of 100° Cent. (212° Fahr.) prior to sieving.

25.—*Method.*—The Committee, after careful investigation, has reached the conclusion that mechanical sieving is not as practicable or efficient as hand work, and, therefore, recommends the following method:

26.—The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one-tenth of 1% passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of large shot. The results should be reported to the nearest tenth of 1 per cent.

Normal Consistency.

27.—*Significance.*—The use of a proper percentage of water in making the pastes* from which pats, tests of setting and briquettes are made, is exceedingly important, and affects vitally the results obtained.

28.—The determination consists in measuring the amount of water required to reduce the cement to a given state of plasticity, or to what is usually designated the normal consistency.

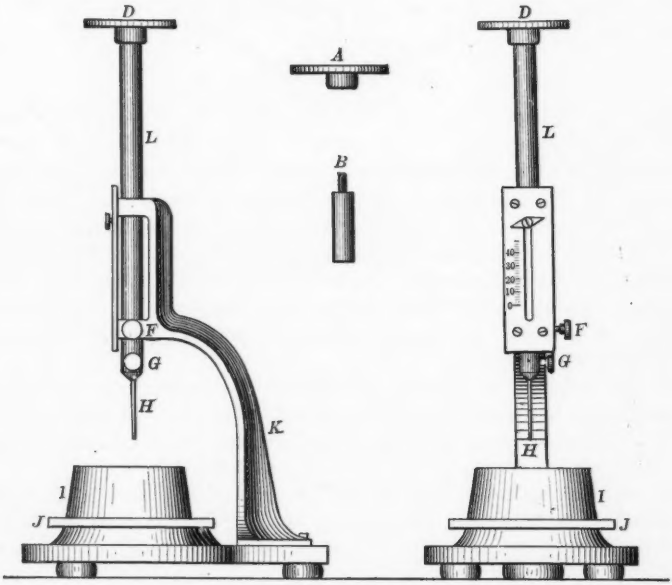
29.—Various methods have been proposed for making this determination, none of which has been found entirely satisfactory. The Committee recommends the following:

30.—*Method. Vicat Needle Apparatus.*—This consists of a frame (*K*), Fig. 2, bearing a movable rod (*L*), with the cap (*A*) at one end, and at the other end the cylinder (*B*), 1 cm. (0.39) in. in diameter, the cap,

* The term " paste " is used in this report to designate a mixture of cement and water, and the word " mortar " a mixture of cement, sand and water.

rod and cylinder weighing 300 gr. (10.58 oz.). The rod, which can be held in any desired position by a screw (*F*), carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame (*K*). The paste is held by a conical, hard-rubber ring (*I*), 7 cm. (2.76 ins.) in diameter at the base, 4 cm. (1.57 ins.) high, resting on a glass plate (*J*), about 10 cm. (3.94 ins.) square.

31.—In making the determination, 500 gr. (17.64 oz.) of cement are kneaded into a paste, as described in Paragraph 58, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 ins. apart; the ball is then pressed into the rubber ring, through the



VICAT NEEDLE.
FIG. 2.

larger opening, smoothed off, and placed on a glass plate (on its large end) and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.

32.—The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

33.—The trial pastes are made with varying percentages of water until the correct consistency is obtained.

34.—The Committee believes that the normal consistency should produce a rather wet paste, since this consistency tends to greater uniformity in the mixing, and there is less liability of compressing the briquettes during the moulding.

35.—Having determined in this manner the proper percentage of water required to produce a neat paste of normal consistency, the proper percentage required for the sand mortars is obtained from an empirical formula.

36.—The Committee hopes to devise such a formula. The subject proves to be a very difficult one, and, although the Committee has given it much study, it is not yet prepared to make a definite recommendation.

Time of Setting.

37.—*Significance.*—The object of this test is to determine the time which elapses from the moment water is added until the paste ceases to be fluid and plastic (called the "initial set"), and also the time required for it to acquire a certain degree of hardness (called the "final" or "hard set"). The former of these is the more important, since, with the commencement of setting, the process of crystallization or hardening is said to begin. As a disturbance of this process may produce a loss of strength, it is desirable to complete the operation of mixing and moulding or incorporating the mortar into the work before the cement begins to set.

38.—It is usual to measure arbitrarily the beginning and end of the setting by the penetration of weighted wires of given diameters.

39.—*Method.*—For this purpose the Vicat Needle, which has already been described in Paragraph 30, should be used.

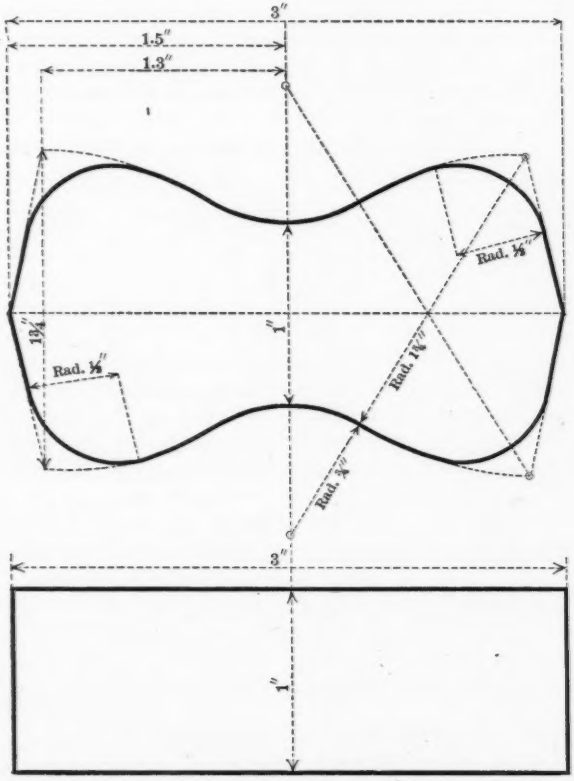
40.—In making the test, a paste of normal consistency is moulded and placed under the rod (*L*), Fig. 2, as described in Paragraph 31; this rod, bearing the cap (*D*) at one end and the needle (*H*), 1 mm. (0.039 in.) in diameter, at the other, weighing 300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

41.—The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

42.—The test pieces should be stored in moist air during the test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

43.—Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces the area and tends to increase the penetration.

44.—The determination of the time of setting is only approximate, being materially affected by the temperature of the mixing water, the



DETAILS FOR BRIQUETTE.

FIG. 3.

temperature and humidity of the air during the test, the percentage of water used, and the amount of moulding the paste receives.

STANDARD SAND.

45.—The Committee recognizes the grave objections to the standard quartz now generally used, especially on account of its high percent-

age of voids, the difficulty of compacting in the moulds, and its lack of uniformity; it has spent much time in investigating the various natural sands which appeared to be available and suitable for use.

46.—For the present, the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, *i. e.*, half the width of the opening in each case.

47.—The Sandusky Portland Cement Company, of Sandusky, Ohio, has agreed to undertake the preparation of this sand, and to furnish it at a price only sufficient to cover the actual cost of preparation.

Form of Briquette.

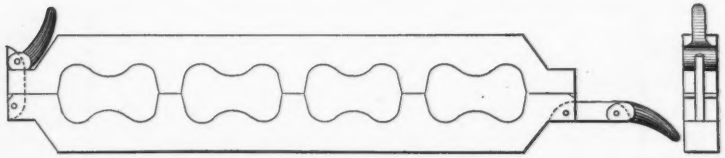
48.—While the form of the briquette recommended by a former Committee of the Society is not wholly satisfactory, this Committee is not prepared to suggest any change, other than rounding off the corners by curves of ½-in. radius, Fig. 3.

Moulds.

49.—The moulds should be made of brass, bronze or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during moulding.

50.—Gang moulds, which permit moulding a number of briquettes at one time, are preferred by many to single moulds; since the greater quantity of mortar that can be mixed tends to produce greater uniformity in the results. The type shown in Fig. 4 is recommended.

51.—The moulds should be wiped with an oily cloth before using.



DETAILS FOR GANG MOULD.

Fig. 4.

Mixing.

52.—All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

53.—The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

54.—The temperature of the room and the mixing water should be as near 21° Cent. (70° Fahr.) as it is practicable to maintain it.

55.—The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbing surface it should be thoroughly dampened prior to use.

56.—The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1 000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

57.—The Committee, after investigation of the various mechanical mixing machines, has decided not to recommend any machine that has thus far been devised, for the following reasons:

(1) The tendency of most cement is to "ball up" in the machine, thereby preventing the working of it into a homogeneous paste; (2) there are no means of ascertaining when the mixing is complete without stopping the machine, and (3) the difficulty of keeping the machine clean.

58.—*Method.*—The material is weighed and placed on the mixing table, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for an additional 1½ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably of rubber.

Moulding.

59.—Having worked the paste or mortar to the proper consistency, it is at once placed in the moulds by hand.

60.—The Committee has been unable to secure satisfactory results with the present moulding machines; the operation of machine moulding is very slow, and the present types permit of moulding but one briquette at a time, and are not practicable with the pastes or mortars herein recommended.

61.—*Method.*—The moulds should be filled at once, the material pressed in firmly with the fingers and smoothed off with a trowel without ramming; the material should be heaped up on the upper surface of the mould, and, in smoothing off, the trowel should be drawn over the mould in such a manner as to exert a moderate pressure on the excess material. The mould should he turned over and the operation repeated.

62.—A check upon the uniformity of the mixing and moulding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3% from the average should not be tested.

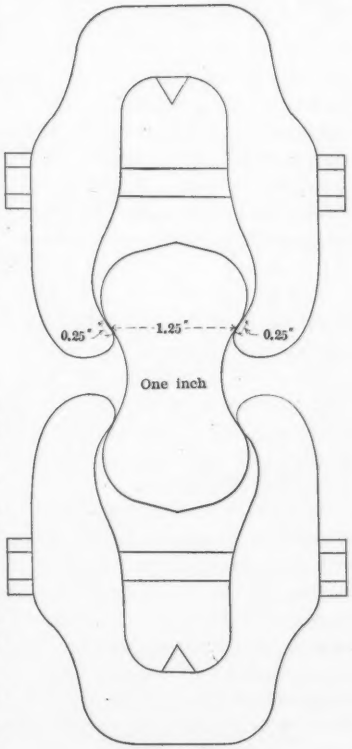
Storage of the Test Pieces.

63.—During the first 24 hours after moulding, the test pieces should be kept in moist air to prevent them from drying out.

64.—A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and, in consequence, all the test pieces are not maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement.

65.—A moist closet consists of a soapstone or slate box, or a metal-lined wooden box—the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.

66.—After 24 hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21° Cent. (70° Fahr.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.



FORM OF CLIP.
Fig. 5.

Tensile Strength.

67.—The tests may be made on any standard machine. A solid metal clip, as shown in Fig. 5, is recommended. This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be ¼ in. wide, and the distance between the center of contact on the same clip should be 1¼ ins.

68.—Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering

the briquettes in the testing machine, as cross-strains, produced by improper centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lbs. per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

Constancy of Volume.

69.—*Significance.*—The object is to develop those qualities which tend to destroy the strength and durability of a cement. As it is highly essential to determine such qualities at once, tests of this character are for the most part made in a very short time, and are known, therefore, as accelerated tests. Failure is revealed by cracking, checking, swelling or disintegration, or all of these phenomena. A cement which remains perfectly sound is said to be of constant volume.

70.—*Methods.*—Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21° Cent. (70° Fahr.), and (2) accelerated tests, or those made in air, steam or water at a temperature of 45° Cent. (115° Fahr.) and upward. The test pieces should be allowed to remain 24 hours in moist air before immersion in water or steam.

71.—For these tests, pats, about 7½ cm. (2.95 ins.) in diameter, 1¼ cm. (0.49 in.) thick at the center, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 ins.) square], from cement paste of normal consistency.

72.—*Normal Test.*—A pat is immersed in water maintained as near 21° Cent. (70° Fahr.) as possible for 28 days, and observed at intervals; the pat should remain firm and hard and show no signs of cracking, distortion or disintegration.

73.—*Accelerated Test.*—(*a*) A pat is placed on a shelf in a suitable vessel filled with fresh water, but without allowing it to touch the bottom. The water is then gradually raised to a temperature of 45° Cent. (115° Fahr.) and maintained at this temperature for 24 hours; or (*b*), a pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel, for 3 hours.

74.—To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion or disintegration.

75.—Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

76.—In the present state of our knowledge it cannot be said that cement should necessarily be condemned simply for failure to pass the accelerated tests; nor can a cement be considered entirely satisfactory, simply because it has passed these tests.

Submitted on behalf of the Committee,

GEORGE S. WEBSTER,
Chairman.
RICHARD L. HUMPHREY,
Secretary.

Committee.
GEORGE S. WEBSTER,
RICHARD L. HUMPHREY,
GEORGE F. SWAIN,
ALFRED NOBLE,
LOUIS C. SABIN,
S. B. NEWBERRY,
CLIFFORD RICHARDSON,
W. B. W. HOWE,
F. H. LEWIS.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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THE PANAMA CANAL.

By George S. Morison, Past-President, Am. Soc. C. E.

To be Presented February 18th, 1903.

On March 5th, 1902, a paper* on one of the most important features of the Panama Canal was presented by the writer. That paper was confined to a single detail, although a very important one. The present paper covers a larger scope, and takes up the principal features of the canal.

The Isthmian Canal Commission, in its report, tried to place the two canals, Panama and Nicaragua, as nearly on the same basis as possible; eliminating from each scheme special advantages and economies which might be applicable on one, but could not be on the other. There were several points on which the writer differed from his colleagues, and, while these differences do not affect the general conclusion, his individual views have influenced the present paper.

Much has been said of the great value of a tide-level canal and its unlimited capacity. This unlimited capacity is more apparent than real. A tide-level canal will require a tide lock at the Pacific end, and, although both gates can be left open at mean tide, so that the length

* "The Bohio Dam," *Transactions*, Am. Soc. C. E., Vol. xlviii, p. 235.

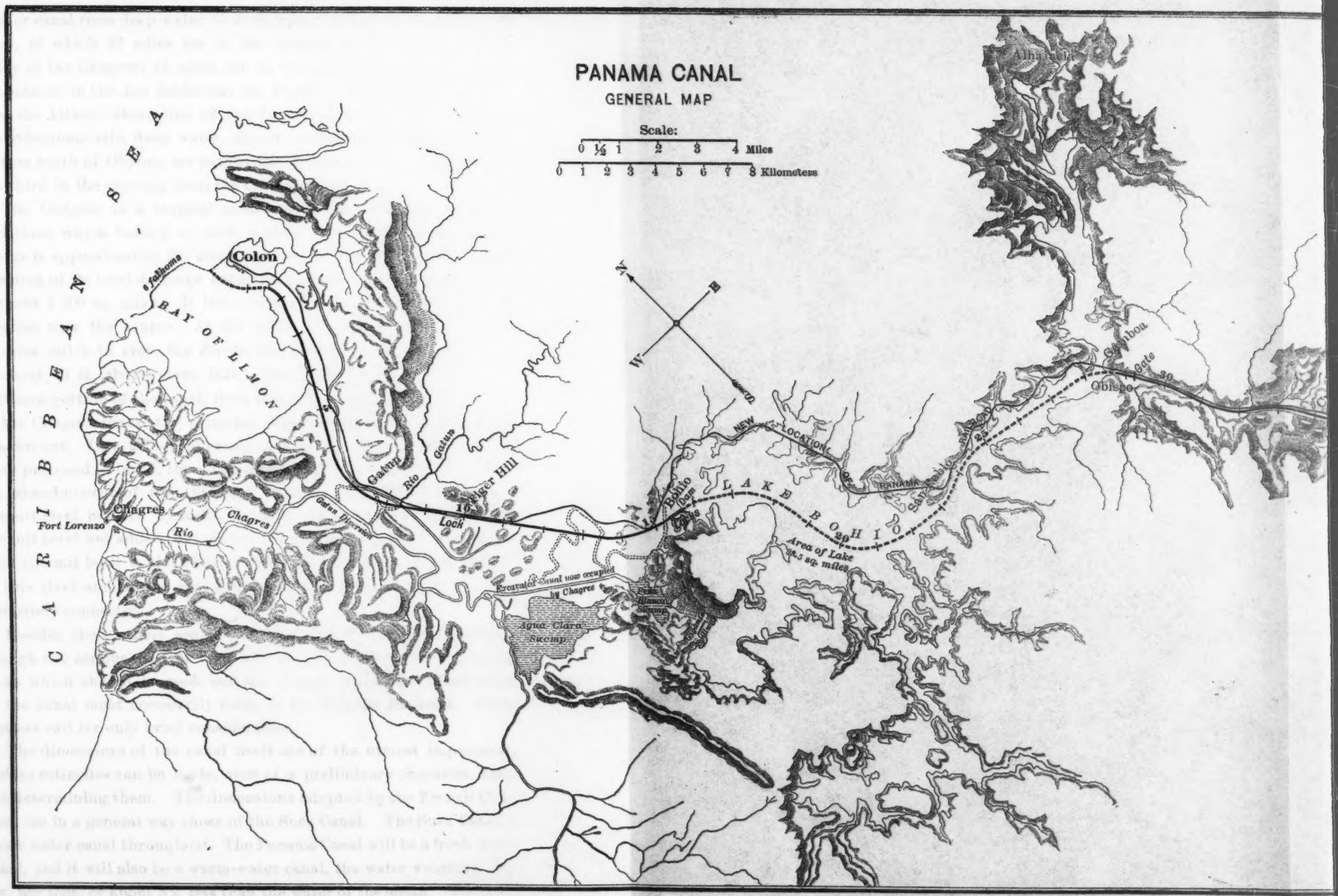
Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

of lock is not a limiting factor, its breadth and depth are. The difficulties of controlling floods are greater in the tide-level canal than in the canal with locks, and the advantage of a broad inland lake is lost. Still, the writer believes that the tide-level canal would be the better canal when done, but that the difficulties which would attend its construction, the greater cost, and especially the longer time involved, preclude its selection. In this paper both plans of canal are described, and comparative estimates given in some detail.

The locks are of enormous dimensions, and, while few engineers would doubt the feasibility of locks 800 ft. long, more than 80 ft. wide, with more than 40 ft. lift, conservatism cautions us against this great lift if it can be avoided. Partly for this reason, the writer has selected the Tiger Hill Cut-Off line for the high-level canal, which permits the rise from the Atlantic to Lake Bohio to be divided into three lifts instead of two, shortens the line, and places it farther from the Chagres. The old location is not condemned, but the cut-off is preferred. The fact that by the use of an intermediate level the head of water against the dam is reduced explains the difference in the seepage figures used in this paper and those calculated in the paper on "The Bohio Dam."

General Description.

At Panama the actual width of the Isthmus from tide water to tide water, in a straight line, is only 35 miles. The continental divide is about 8 miles from the Pacific, and in places less than 300 ft. above mean tide. Between this low mountain ridge and the Atlantic lies a hilly country, intersected by streams, the drainage of which is into the Atlantic through the Chagres River. The Chagres rises in the mountains about 60 miles east of the canal location and enters the Caribbean Sea some miles west of the Atlantic terminus of the canal. The valley of the Chagres, with the low country adjacent to it, forms a natural approach from the Atlantic side. To pass from this valley to the Pacific, it is necessary to go boldly across the low ridge of the Cordilleras. The route selected by the original French company for the Panama Canal is, in a general way, the same as that on which the Panama Railroad was built 30 years before. Subject to variations of detail, the routes are practically one, and the only possible route in this part of the Isthmus. The total distance by either rail-


PANAMA CANAL
GENERAL MAP
Scale:
0 ½ 1 2 3 4 Miles
0 1 2 3 4 5 6 7 8 Kilometers
CARIBBEAN SEA
Colon
6 fathoms
BAY OF LIMON
Chagres
Fort Lorenzo
Chagres River
Gatun
Gatun River
Gatun Diversion
Gatun Lake
Miraflores Lake
Miraflores Locks
Pedro Miguel Locks
Culebra Cut
Bohio
Bohio Dam
Dike
LAKE BOHIO
Area of Lake 164.5 sq. miles
NEW LOCATION
PANAMA R.R.
Panama
Sabanas
Balboa
Cristobal
Gamboa
Gatun
Obispo
Excavated Canal now occupied by Chagres
Agua Clara Swamp
Pedro Miguel Swamp
Miraflores Swamp
Miraflores
Miraflores Dam
Pedro Miguel
Pedro Miguel Dam
Culebra
Culebra Dam
Gaillard Cut
Bas Obispo
Alhajuela
N
W
E
S

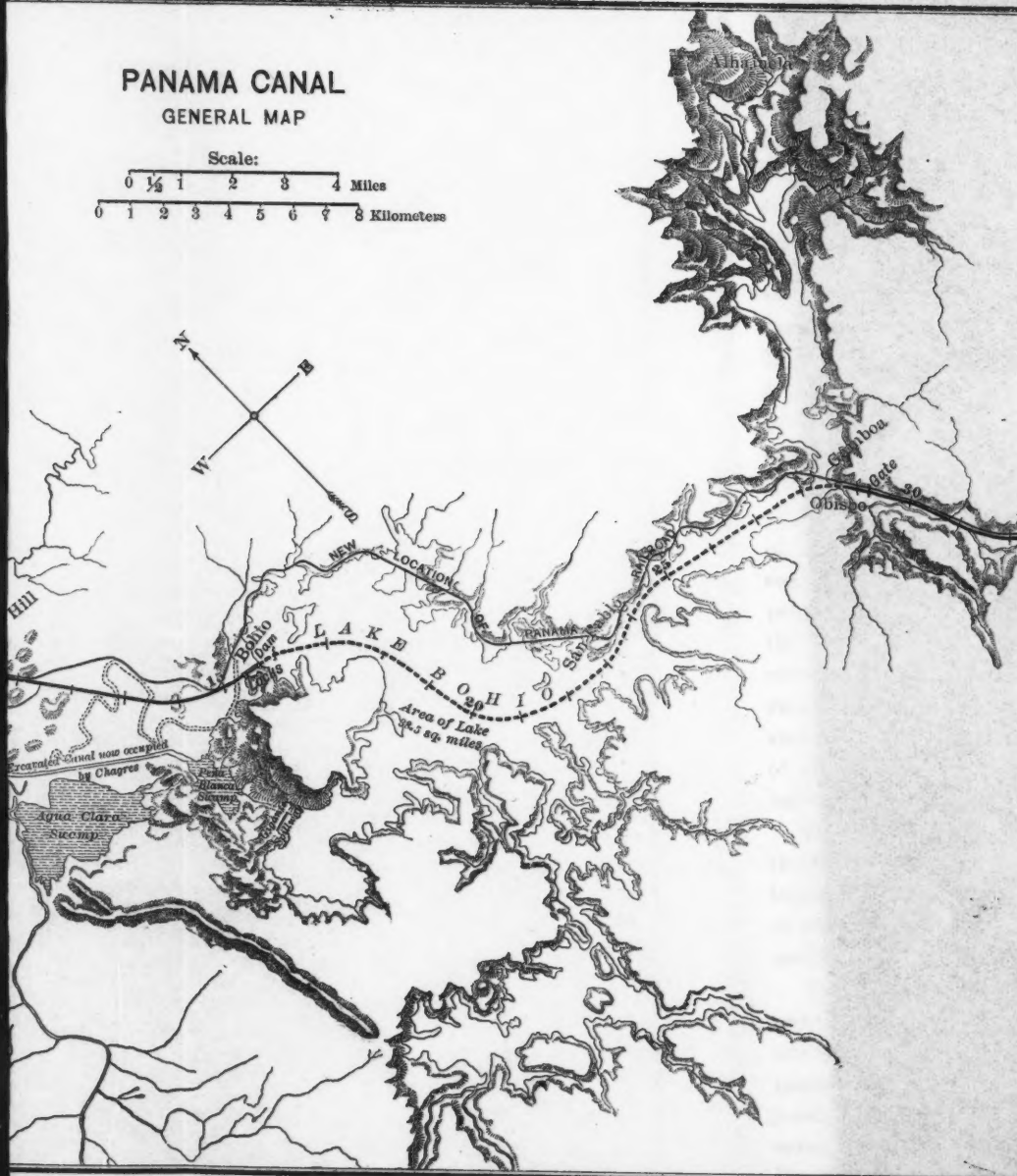
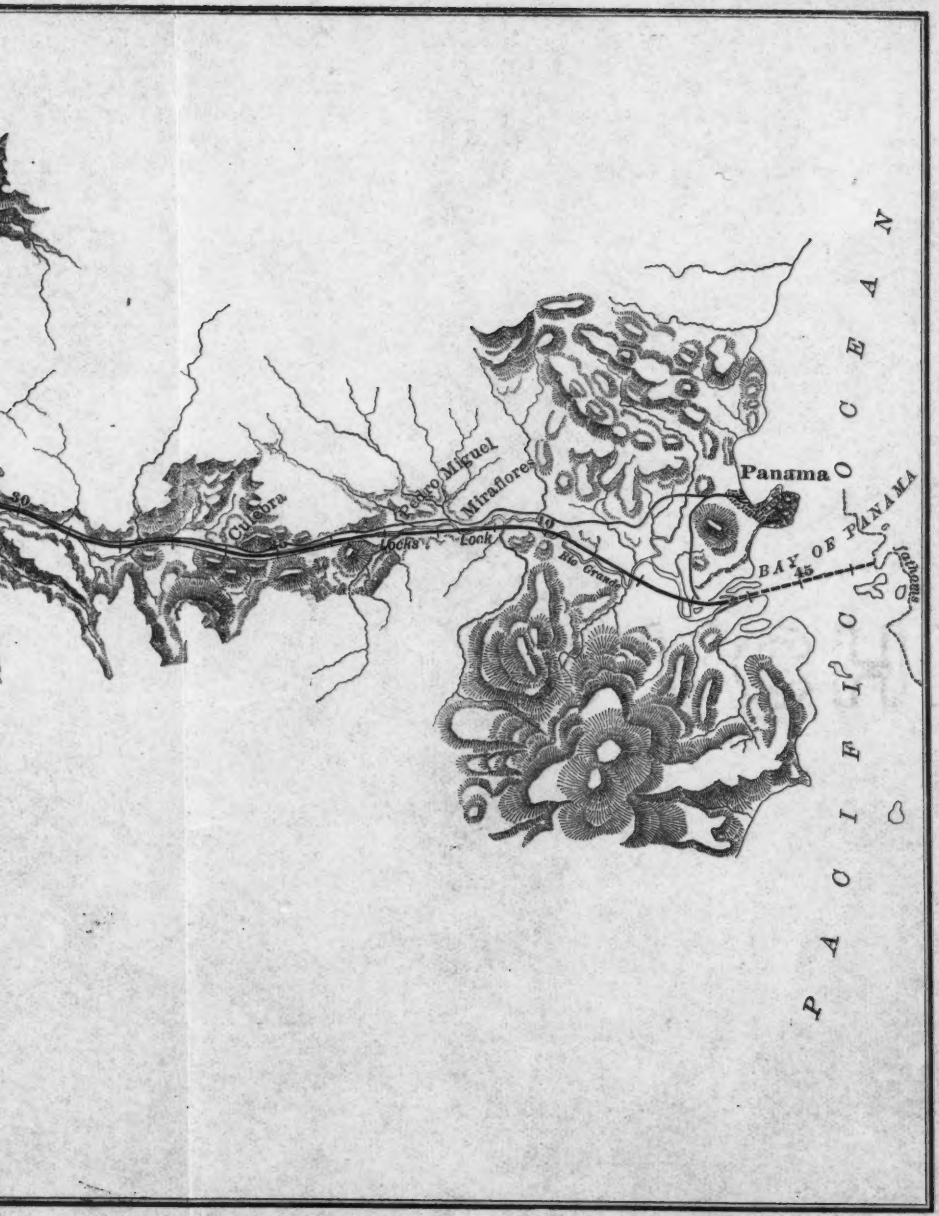

PANAMA CANAL
GENERAL MAP
Scale:
0 ½ 1 2 3 4 Miles
0 1 2 3 4 5 6 7 8 Kilometers
N
E
W
S
Gamboa
Gatun
Obispo
NEW LOCATION
PANAMA R.R.
Culebra Cut
Gold Hill
Bohio
Bohio Dam
Locks
LAKE BOHIO
Area of Lake
85 sq. miles
Excavated Canal now occupied by Chagres
Agua Clara Swamp
Bohio Blanco Swamp

PLATE I.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
MORISON ON PANAMA CANAL.





road or canal from deep water to deep water is, in round numbers, 45 miles, of which 27 miles are in the Atlantic coastal plain and the valley of the Chagres; 12 miles are in the passage of the ridge, and the balance in the low lands near the Pacific. Of the actual distance from the Atlantic shore line to the Pacific shore line, not including the extensions into deep water, almost exactly two-thirds, being the portion north of Obispo, are within the drainage of the Chagres, and one-third in the crossing from the Chagres to the Pacific.

The Chagres is a tropical mountain stream, with the excessive variations which belong to such a river. Its maximum flood discharge is approximately 200 times its minimum dry-season discharge. The area of its total drainage basin, though not completely surveyed, is about 1 200 sq. miles. It has a comparatively rapid fall, which is greatest near the source. At the point where the canal leaves the Chagres valley to cross the divide, the bottom of the Chagres River is about 40 ft. above mean tide. The principal difficulties of the northern portion of the canal, from Colon to Obispo, lie in the control of the Chagres River; the principal difficulty on the remainder is the summit cut. In a tide-level canal, such as the original French Company proposed to build, these two difficulties were virtually all. With the abandonment of the tide-level scheme and the adoption of a summit level reached by locks, the problem of water supply for this summit level was added, but, as the only source of gravity supply for such summit level is the Chagres River, the problems of the control of this river and of the use of its water to feed the canal are very intimately connected.

Besides these, there are the harbors, which present difficulties, though not serious ones, at each end of the canal; the dimensions of locks which should be used, and the changes which the construction of the canal must necessarily make in the Panama Railroad. These matters call for only brief consideration.

The dimensions of the canal itself are of the utmost importance, and no estimates can be made, even of a preliminary character, without determining them. The dimensions adopted by the French Company are in a general way those of the Suez Canal. The Suez Canal is a salt-water canal throughout. The Panama Canal will be a fresh-water canal, and it will also be a warm-water canal, the water weighing 62.2 lbs. per foot, or about 3% less than the water of the ocean. The Suez

Canal has a depth of 9 m., or 29.5 ft. To accommodate ships of equal size, the Panama Canal should be at least 8 ins. deeper. The Suez Canal cannot accommodate the largest class of ships; the regulations of that canal limit the draft of ships passing through it to 7.8 m. or 25 ft. 7 ins., though ships of greater draft are sometimes taken through with the assistance of tugs. The largest steamers now plying between England and Australian ports cannot and do not pass through the Suez Canal. There is a large number of ships now in service on the Atlantic, the authorized draft of which is 32 ft. or more; one of these ships would draw 33 ft. in the Panama canal. The traffic which would pass through the Panama Canal would be of a character materially different from that which uses the Suez Canal; it would consist largely of heavy, coarse freight. As the size of a ship is, in a measure, a function of the length of voyage, it is probable that the largest class of freight carriers will use this canal. The Isthmian Canal Commission considered that the canal should have a depth of 35 ft., through which steamers drawing 32 ft. in salt water could pass without trouble, and the writer concurs in this decision.

In determining the width of the canal there is more room for difference of opinion. While depth may be considered a necessity, width is very largely a convenience. A ship can be taken through a canal with little clearance on either side, but it must be done very slowly; a much greater width will be required if any considerable speed is to be maintained, and still more if large ships are to pass each other in all portions of the canal. The dimensions adopted by the original French Company provided for a bottom width of only 22 m., or 72 ft.; the new French Company adopted a bottom width of 30 m., slightly increased in rock sections, or a little less than 100 ft. The Isthmian Canal Commission selected a bottom width of 150 ft., which was somewhat enlarged on curves. The increased width on curves in so large a canal is perhaps an over-refinement, but, in view of the experience of other great works, it is probably not wise to reduce the dimensions selected by the Commission.

Colon Harbor is virtually tideless, while Panama Bay has a tidal range of over 20 ft. The plans of the original French Company contemplated a depth of 9 m. below mean water at both termini, which would have made a channel of about 20 ft. at low water in Panama Bay. The plans of the new French Company proposed a depth of 9 m. below

low water in Panama Bay; the Isthmian Canal Commission's estimates are based on a depth of 35 ft. below mean low water in Panama Bay. A depth of 35 ft. below mean tide in Panama Bay would give 25 ft. in the canal under all conditions, 45 ft. at high water and 35 ft. for about 18 hours out of 24. In the opinion of the writer, this depth is quite as much as the demands of traffic are likely to justify.

With this preliminary statement, the main features of the canal may be described.

Control of the Chagres.

The discharge of the Chagres has been made a matter of special observation by the new French Company, and these observations have been verified and amplified by Arthur P. Davis, M. Am. Soc. C. E., for the Isthmian Canal Commission. While the conclusions from such studies cannot be regarded as absolutely accurate, the general conditions, of which little was known twenty years ago, may now be considered established. The greatest flood in the Chagres, of which there is any record, occurred in 1879, prior to the beginning of work by the old French Company. The two floods of which there is the most accurate information are those of 1890 and 1893.

The area of the drainage basin of the Chagres above Bohio, the location selected by the French Company for a dam, is estimated at 875 sq. miles. This watershed may be divided for convenience into three parts: the portion above Alhajuela, the point selected by the French Company for the upper dam; the portion between Alhajuela and Gamboa, which is practically the point where the canal leaves the river; and the portion between Gamboa and Bohio. The area of the upper division is approximately 510 sq. miles, of the middle division 135 sq. miles, and of the lower division 230 sq. miles. The areas of the watersheds above these three points, will, therefore, be as follows:

	Square miles.	Percentages.
Alhajuela	510	58
Gamboa	645	74
Bohio	875	100

The data concerning the flood of 1879 are meager, and consist only of water marks from which the discharge has been calculated on various assumptions, while there is no accurate information by which the duration of the flood or the aggregate discharge can be even approxi-

mately determined. The conclusions, generally, are to the effect that it was in excess of 70 000 cu. ft. per second at Gamboa and 100 000 cu. ft. per second at Bohio. The general opinion has been that these figures are too high, but Mr. Davis thinks that there is a possibility that they are too low and that the flood may have been nearly 100 000 cu. ft. per second at Gamboa, and have exceeded 130 000 cu. ft. per second at Bohio. The flood of 1890 attained a maximum of 75 000 cu. ft. per second at Bohio, and that of 1893 fell below 50 000 cu. ft. per second. All these floods were of very short duration, the average discharge of the Chagres being about 2 000 cu. ft. per second at Alhajuela, 2 500 cu. ft. at Gamboa, and 4 000 cu. ft. at Bohio. The time in which the discharge at Gamboa would exceed 35 000 cu. ft. per second, or that at Bohio 50 000 cu. ft. per second, would probably not be more than ten days in twenty years. A suspension of traffic during these few days would not seriously reduce the value of the canal.

If a flood of 35 000 cu. ft. per second coming from the upper Chagres at Gamboa and of 50 000 cu. ft. at Bohio could be so regulated that it would not produce a speed much exceeding 3 ft. per second in the navigable portions of the canal the commercial requirements would be met. The canal, however, must be so designed that a maximum flood would do no permanent harm, and this means a probable discharge of 100 000 cu. ft. per second at Bohio, with the possibility that 140 000 cu. ft. per second should be provided for. A speed of 3.3 ft. (1 m.) per second could be allowed in the canal without disturbing navigation; a speed of 5 ft. per second could be allowed without permanent injury to the work.

With these conditions, a channel of 15 000 sq. ft. cross-section would carry off a flood of 50 000 cu. ft. per second without interfering with navigation, and of 75 000 cu. ft. per second without injury to the canal. If a tide-level canal is to be built, it must either be given these dimensions in the Chagres Valley or independent channels must be provided to carry off the discharge of the river. As the canal is in the lowest part of the valley, the construction of these channels would be a matter of serious difficulty, and the simplest solution would be to make a canal large enough to take the full discharge, which would have the further advantage of furnishing a very large canal, in which navigation, under ordinary conditions, would be especially easy; this would mean a canal with a bottom width of about 400 ft. An approximate

estimate shows that the total amount of excavation for such a canal between Colon and Obispo would be 150 000 000 cu. yds., about one-sixth of which is likely to be rock. This channel, however, has practically no factor of safety, and, if the flood of 1879 should be repeated, it might prove inadequate. By building the dam proposed by the French Company at Alhajuela the discharge above that point could be temporarily stored, and the discharge through the lower valley kept within the capacity of the proposed canal. It may be roughly estimated that the cost of this Chagres section of a tide-level canal would be about $90 000 000. While this treatment would be heroic, it is practicable, and would be satisfactory when done.

If, however, a dam could be built across the valley of the Chagres, the whole valley would be converted into a lake of such dimensions that the currents in this lake, even during the most violent floods, would not be objectionable. This is, perhaps, the greatest advantage to be gained by using locks and a summit level, it is certainly second only to the reduction in the volume of the Culebra Cut. The further down the valley this dam can be placed, the greater will be the length of valley converted into lake. The lowest point, however, which has been found in any way suitable for a dam site is at Bohio, midway between Obispo and the terminus of the canal at Colon. A site for a dam in this neighborhood has been selected by the new French Company, and the Isthmian Canal Commission concurred in the expediency of building a dam in the same vicinity. By the construction of such a dam the valley is converted into a lake between Obispo and Bohio, and this lake would extend up the upper valley of the Chagres to a distance determined by the height of the dam. The Gigante, a lateral stream coming from the west, enters the Chagres about 4 miles above Bohio, and near the head of this stream is a low summit admirably adapted for a spillway. The limits within which the range of the lake could be confined would be determined by the length of this spillway. The Isthmian Canal Commission has proposed a spillway 2 000 ft. long. Using the formula

$$Q = 3.5\, h^{\frac{3}{2}}\, l,$$

we have the following results, if l is made 2 000:

$Q =$ 50 000	$h = 3.71$
75 000	4.86
100 000	5.89

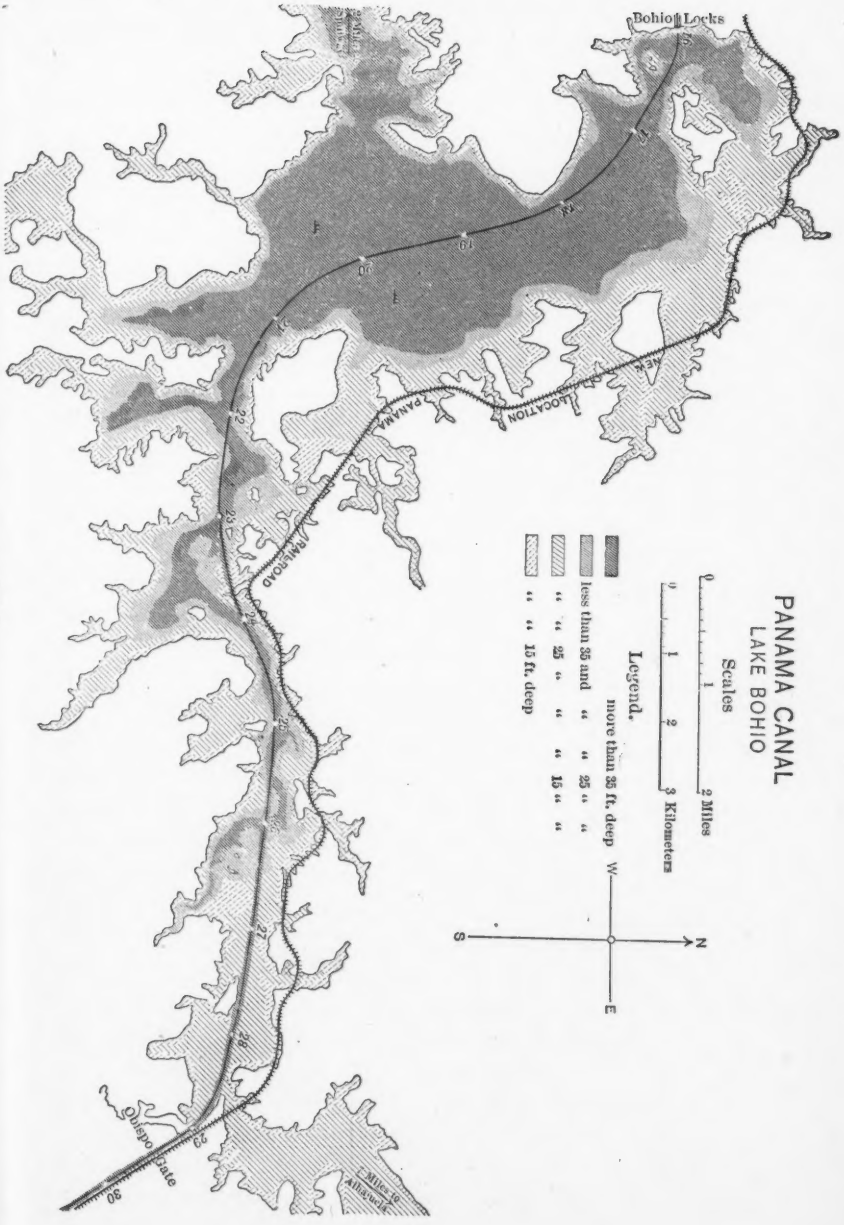
It would appear, therefore, that heights of, respectively, 4, 5, and 6 ft. over the crest of the spillway would pass something more than 50 000, 75 000 and 100 000 cu. ft. per second for an indefinite period. The maximum floods, however, are of short duration, and a considerable amount would be stored in the lake, as its level is raised from the normal level to the extreme height of such a flood. With the surface of the lake at Elevation 85, corresponding to a bottom level at Elevation 50, as used in estimating the Culebra Cut, the surface area of this lake is 38.5 sq. miles, or about 1 075 000 000 sq. ft. A rise from a depth of 1 ft. to a depth of 5 ft. over the spillway would represent a storage of 4 300 000 000 cu. ft., an average of 50 000 cu. ft. per second for 24 hours, or 25 000 cu. ft. per second for two days. A detailed study shows that, with a discharge of 100 000 cu. ft. per second into the whole basin, the discharge is never likely to exceed 75 000 cu. ft. per second over the spillway, and 5 ft. may be accepted as the variation in the level of the lake. Should a greater flood occur it would merely mean a little higher level in the lake, which might possibly rise to about 6 ft. above the crest of the spillway. Furthermore, the canal through the Culebra Cut would have a cross-section, during this high water, of over 6 000 sq. ft., capable of taking off, at 5 ft. per second, a discharge of 30 000 cu. ft. per second; and the canal north of the Bohio Dam would have a cross-section of not less than 7 000 sq. ft., capable of taking off, at a speed of 3 ft. per second, 21 000 cu. ft. per second.

This general arrangement means a lake the surface of which varies from Elevation 85, when level with the top of the spillway, to Elevation 90, under extreme flood conditions, with a bare possibility of reaching Elevation 91. It involves a spillway at Gigante and a dam at Bohio, of which structures more will be said hereafter. Comparatively little excavation would be required in any portion of the lake, the total between the Bohio Dam and Obispo being barely 2 000 000 cu. yds,, of which, perhaps, one-fourth is rock, and the total cost of which would not exceed $1 000 000.

Below the Bohio Dam the old French location followed the valley of the Chagres about 9 miles to Gatun, where the Chagres turns abruptly to the west and enters the Caribbean Sea some miles west of Colon. This is, perhaps, the only location for a tide-level canal. For 4 miles of this distance the Chagres has absolutely abandoned its old course and flows through the canal. The discharge over the Gigante



Fig. 1.

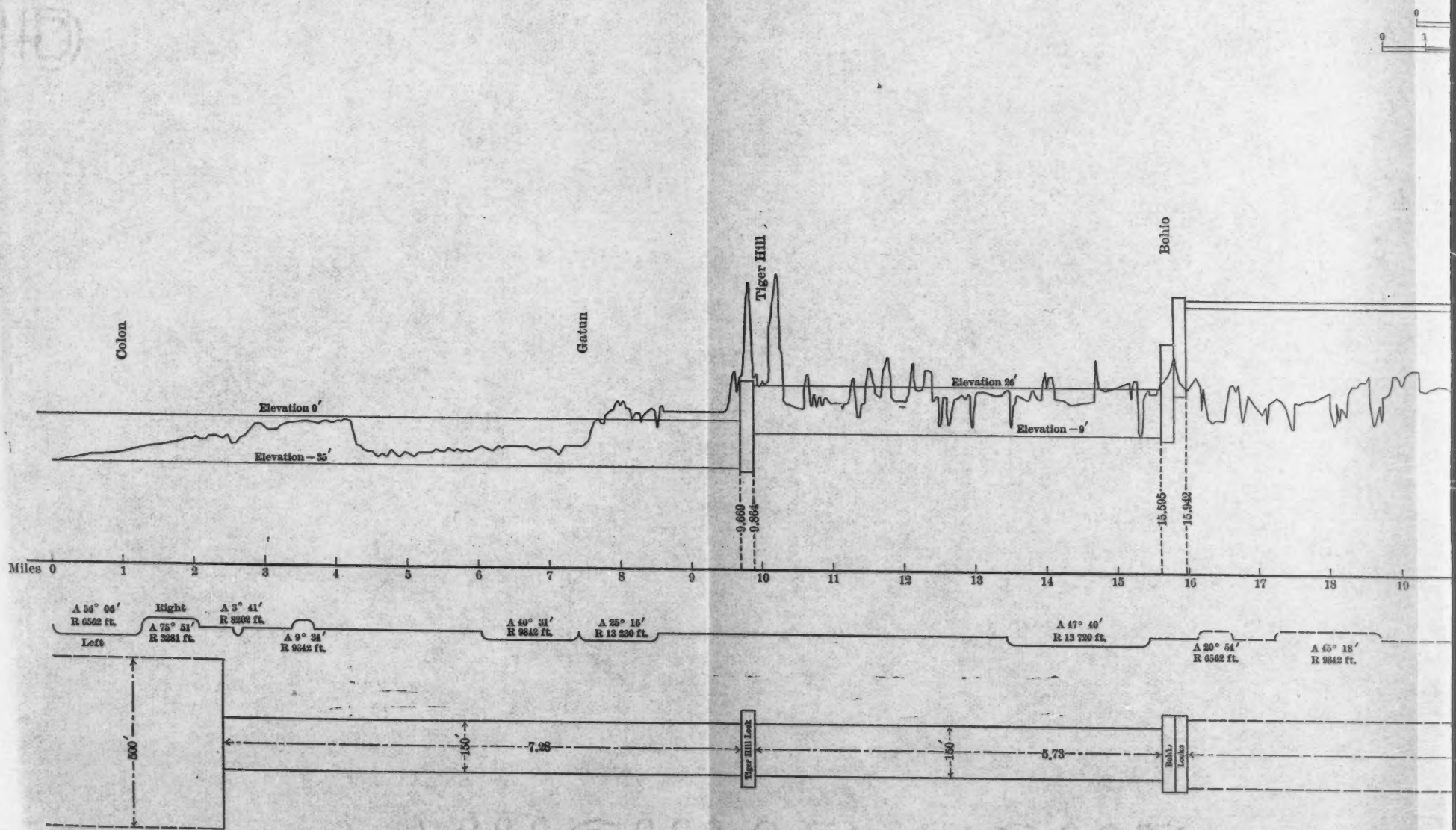

PANAMA CANAL
LAKE BOHIO
Scales
0 1 2 Miles
0 1 2 3 Kilometers
Legend.
more than 35 ft. deep
less than 35 and " " 25 " "
" " 25 " " " 15 " "
" " 15 ft. deep
W
E
S
N
Bohio Locks
Gamboa
Obispo Gate
Miraflores
Miraflores Locks
Panama
Culebra Cut
Gatun Locks
Gatun Dam
Gatun
Mindi
Mindi Creek
Chagres River
Gatun Lake
Bohio
Alhajuela
Alhajuela Creek
Obispo
Obispo Creek
Miraflores Lake
Miraflores Creek
Panama Railroad
Panama Canal
Old Panama Canal Location
Old Panama Canal Location
Old Panama Canal Location

Spillway will enter the Chagres about 2 miles below Bohio; below this point one of three courses is practicable. The same course may be adopted that is proposed for a tide-level canal, giving the canal a section of such dimensions that it could pass the flood discharge within its own limits. The valley here is generally comparatively broad, and the floods can be kept out of the canal by constructing a levee on the west side of it; this plan involves a discharge channel between the two swamps, Peña Blanca and Agua Clara, besides which a new channel for the Chagres must be dug across a neck of land opposite Gatun and about three-quarters of a mile from the canal. A location can be adopted east of the Chagres valley, between Bohio and Gatun, by which the canal can be kept a safe distance from the Chagres and for half the way at a safe height above it. This third plan has the advantage of saving 1¼ miles of distance. Furthermore, there is an excellent site for a lock at Tiger Hill, 6 miles from Bohio, by which it is possible to reduce the lift of the Bohio locks. This last line is preferred by the writer, and is used in this description. It is the line shown on the general map, Plate I. The level of the surface of the canal is maintained at 26 ft. above mean tide south of the Tiger Hill lock, the bottom of the canal being 9 ft. below mean tide. The one defect of this plan is that the water is carried a few feet above the level of the surrounding country, but there is such an enormous excess of excavation in the canal that an embankment of almost indefinite width can be built on the river side. This line joins the French location at Gatun, and the new channel for the Chagres opposite Gatun is still necessary.

The problem of the control of the Chagres is absolutely solved by the construction of three works: the Bohio Dam, the Gigante Spillway and the Gatun Diversion.

Water Supply.

The only source from which a supply of water for the summit level can be obtained by gravity is the Chagres River. The French plan, which contemplated a summit level above that of the lake, proposed to build a dam at Alhajuela and convey the water by a feeder, of complicated design, from the dam to the summit. The same arrangement was proposed by Captain E. P. Lull, U. S. N., in 1875. If the lake itself be made the summit level, any such feeder becomes unnecessary, and the canal will be fed at all times by the Chagres River and the


Colon
Gatun
Tiger Hill
Bohio
Elevation 0′
Elevation −35′
Elevation 26′
Elevation −9′
0.660
0.864
15.505
15.942
Miles 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
A 56° 06′ R 6562 ft. Left
A 75° 51′ R 3281 ft. Right
A 3° 41′ R 9302 ft.
A 9° 34′ R 9842 ft.
A 40° 31′ R 9842 ft.
A 25° 16′ R 13 230 ft.
A 47° 40′ R 13 720 ft.
A 20° 54′ R 6562 ft.
A 45° 18′ R 9842 ft.
500′
150′
7.28
Tiger Hill Lock
150′
5.73
Bohio Locks

PANAMA CANAL

PROFILE

Scales

0 1 2 3 4 Miles

0 1 2 3 4 5 6 7 8 Kilometers

------ Original ground surface

– – – – Drowned channel

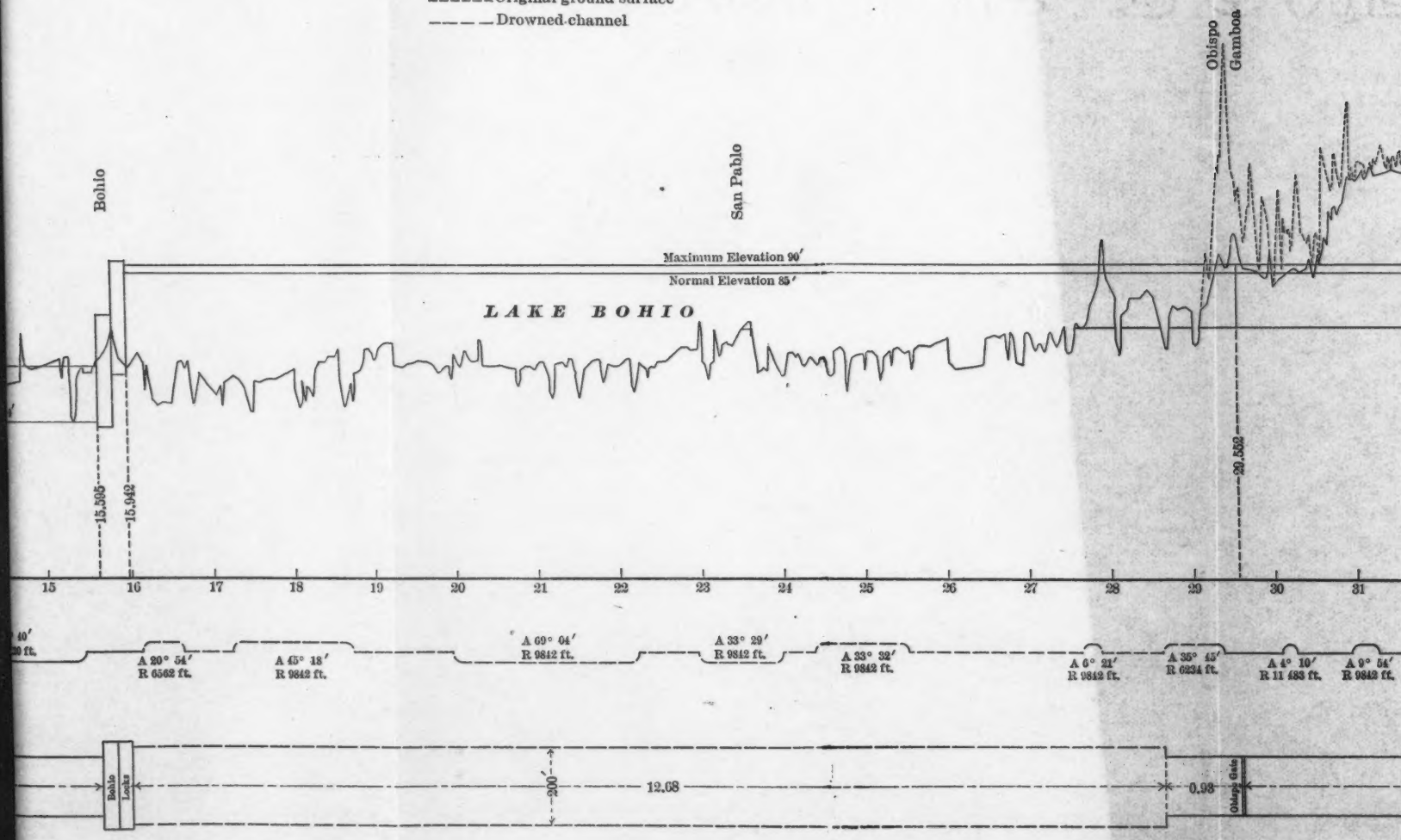
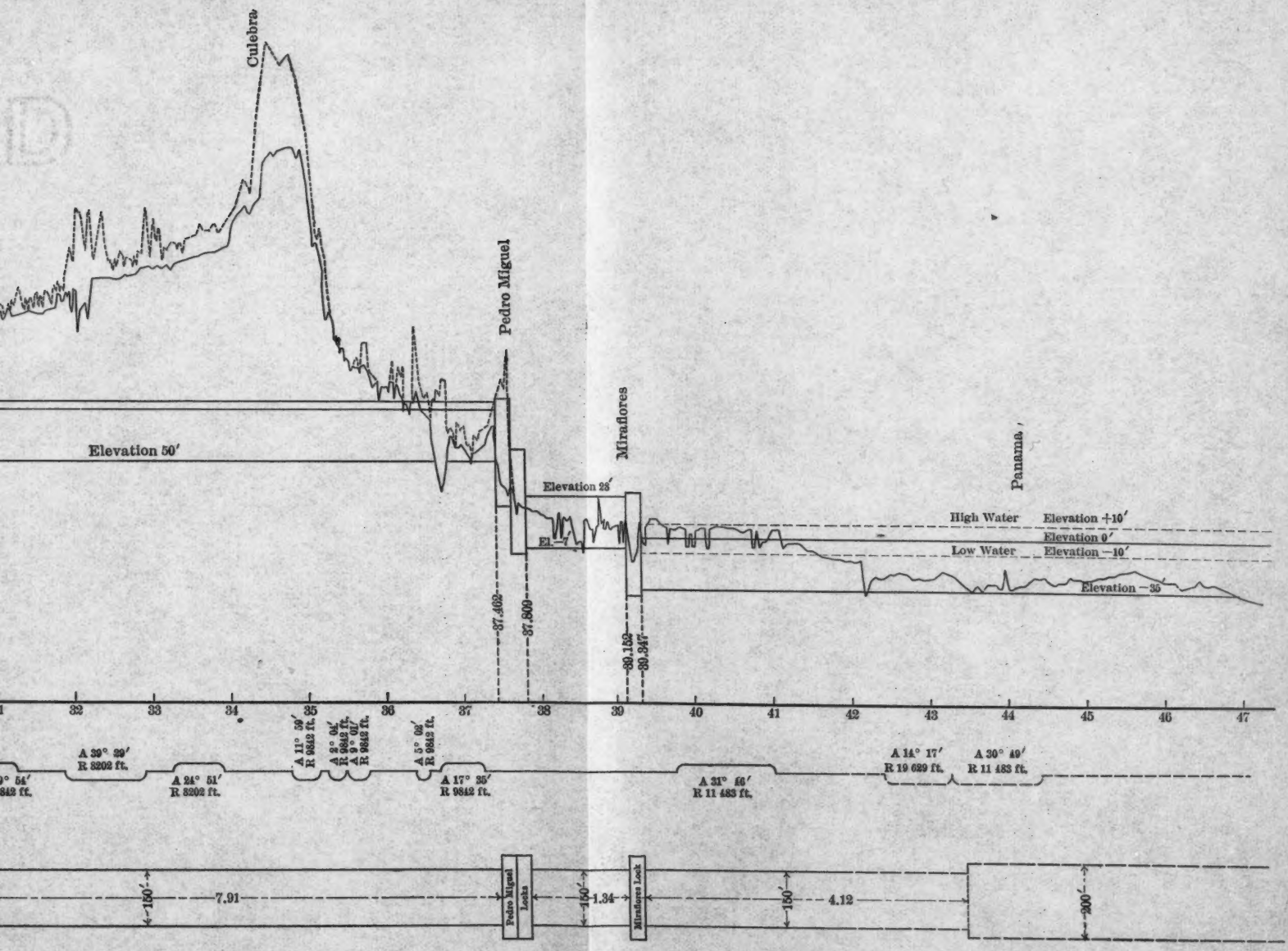


PLATE II.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
MORISON ON PANAMA CANAL.



various tributaries which are intercepted by the lake. Were the discharge of the Chagres and its various affluents at all times equal to the demands of the canal, no further provision would be required. There is, however, a short period in the early part of each year when the supply is always small and sometimes inadequate. The actual demands for water for canal uses may be limited to three purposes: lockage, seepage and evaporation. Besides this, the French estimates have made provision for power, but this is hardly an actual necessity of the canal, and can be provided in other ways, if the water supply is inadequate. Furthermore, the amount of water actually needed for power is, in the aggregate, exceedingly small.

With the water in the lake at a normal elevation of 85 there will be a descent of 59 ft. to the intermediate level on the Atlantic side, and of 59 ft. to the intermediate level on the Pacific side, an average of 58 ft. Each descent is accomplished by two locks, the average lift of which, in the period when an economy of water is important, is 29 ft. These locks, according to the plan adopted by the Isthmian Canal Commission, are 84 ft. wide and 790 ft. long between gates; each lock chamber contains, therefore, 1 924 470 cu. ft. If it be assumed that ten vessels pass through the canal daily, each using two full locks of water, one ascending and one descending, the total daily consumption will be 38 488 800 cu. ft., or 445 cu. ft. per second. This amount will be reduced materially if intermediate gates are provided in the locks so that smaller vessels can take less than a lockfull of water.

The seepage will be confined principally to the Bohio Dam. There is a short piece of embankment near the Gigante Spillway, but it is of such insignificant dimensions as to be of no importance. Elsewhere, the summit lake is confined between the natural walls of mountain valleys. Estimated on the basis used in the paper on "The Bohio Dam," but with the head reduced to 60 ft., the requirement for seepage would be 28 cu. ft. per second.

To the seepage proper must be added the waste of water the locks. This will depend very largely on gate construction, character of valves, and care of lock tenders. A provision of 200 cu. ft. per second would seem to be ample.

The area of the lake is 38.5 sq. miles, or 1 075 000 000 sq. ft., and the evaporation over this area, taken at 0.5 ft. per month, or 0.0167 ft. per day, or 0.00000019 ft. per second, amounts to 207 cu. ft. per second over the whole area of the lake.

This makes the entire water requirement, with no provision for power, 880 cu. ft. per second. These figures will vary on different assumptions, but it is safe to say that 1 000 cu. ft. per second would be a generous supply for any traffic that is yet in sight. Furthermore, with the tendency to increase the size of ships, it is probable that the actual number of ships will be less, rather than more, than ten daily.

In a general way, it may be said that, out of a total of 1 000 cu. ft. per second, 450 cu. ft. will be required for lockage, 250 cu. ft. for seepage and leakage at gates, and 200 cu. ft. for evaporation, leaving 100 cu. ft. per second for margin and power. This quantity of water, 100 cu. ft. per second, falling 85 ft., will produce about 800 H.-P. on the shaft of a turbine wheel.

The average monthly discharge of the Chagres at Bohio always exceeds 1 000 cu. ft. per second, except during a period of varying length in the months of February, March, April and May. It may have fallen as low as 350 cu. ft. per second for a few days. The French Company has kept daily observations at Bohio of the stage of water for about ten years. From these stages the daily rates of discharge have been calculated, and from these results it is easy to determine the deficiencies, below an average of 1 000 cu. ft. per second, which have occurred during the period of these observations. These deficiencies for nine years are shown in Table No. 1, the last column of which shows the depth of water in the lake corresponding thereto.

TABLE No. 1.

Year.	Cubic feet.	Feet.
1891	2 600 000 000	2.42
1892	291 600 000	0.27
1893	1 166 400 000	1.09
1894	637 000 000	0.60
1895	864 000 000	0.80
1896	648 000 000	0.61
1897	1 728 000 000	1.61
1898	Records incomplete.	
1899	172 800 000	0.16
1900	1 296 000 000	1.21
1901	230 000 000	0.21
1902	0	0.

There are several ways to provide for this deficiency. The first would be to take it from the lake, which has an area of 1 075 000 000 sq. ft.; the last column of Table No. 1 shows that this reduction would still leave it possible for ships drawing 30 ft. at sea to pass through. Another method would be to lower the bottom of the canal through the summit level 3 ft.; this is the plan proposed by the Isthmian Canal Commission; it would add about 1 500 000 cu. yds. to the Culebra Cut, besides increasing the height of the long retaining walls and the cost of the locks; it may be roughly estimated as adding from $2 500 000 to $3 000 000 to the cost of the canal. Another method would be by the construction of the Alhajuela Dam, proposed by the French Company, by which a lake could be formed in the upper Chagres Valley, in which 15 000 000 000 cu. ft. of water could be stored. If the construction of this dam were deferred until after the completion of the other work, so that the lake could be used for transporting material, Elevation 85 carrying still water almost to the site of the dam, the cost of the dam would not exceed the cost of deepening the lake, and it would have the further advantage of storing water above the dam, by which the violence of the floods below the dam would be diminished. A fourth method would be by the use of the old Yankee device of flash-boards, by which the level of the lake could easily be raised 3 ft. above the crest of the spillway, without involving any increase in the height of water during extreme floods. In the judgment of the writer, the canal should be opened with no special provision for additional water supply during the dry months, other than what would be obtained by lowering the level of the lake or by the use of flash-boards. Experience will show what additional storage is required, and, if needed, it can be more economically provided after the other works are completed than before.

Ten lockages each way daily represent the passage of 3 650 ships a year, if no two ships are ever passed together through the same lock at the same time. This would undoubtedly be done occasionally with small vessels. If 10% is added on this account, they represent a passage of 4 000 ships a year, and if these have an average of 2 500 tons, net, they represent a total of 10 000 000 tons yearly. The number of ships passed through the Suez Canal in 1901 was 3 699, the average net tonnage being 2 926 tons. It is probable that the average net tonnage will be at least 4 000 tons when the Panama Canal is opened, and that ten lockages each way daily would represent at least 15 000 000 tons.

It is important, however, to consider the possibilities of water supply for larger traffic. Of the 1 000 cu. ft. per second required for the wants of the canal, 450 cu. ft. are consumed in lockage. If, therefore, the number of lockages is doubled, representing a passage of at least twenty ships daily, the requirements are 1 450 cu. ft. per second; thirty passages would require 1 900 cu. ft. per second, and forty passages 2 350 cu. ft. per second. The length of time when the discharge of the Chagres falls below these requirements increases with the amounts, but in no instance of which we have any record has it fallen below the maximum requirement of 2 350 cu. ft. per second for a continuous period of more than four months. The deficiencies below these requirements are given in Table No. 2, and are shown in the diagram, Fig. 2.

TABLE No. 2.

Year.	Below 1 450 cu. ft.	Below 1 900 cu. ft.	Below 2 350 cu. ft.
1891	5 437 000 000	9 435 000 000	13 712 000 000
1892	1 069 200 000	2 575 600 000	6 505 900 000
1893	2 760 500 000	5 376 500 000	8 456 700 000
1894	3 164 200 000	6 531 600 000	11 095 700 000
1895	2 140 600 000	5 056 600 000	8 084 900 000
1896	2 708 600 000	5 585 700 000	8 873 900 000
1897	4 060 800 000	7 171 200 000	10 476 000 000
1898	1 555 000 000	3 382 000 000	6 363 000 000
1899	2 702 400 000	5 546 300 000	9 977 900 000
1900	4 523 000 000	8 217 000 000	12 494 000 000
1901	4 900 840 000	8 985 140 000	13 261 940 000
1902	505 400 000	2 605 000 000	5 326 600 000

To meet this deficiency it will be necessary to build a dam at or near Alhajuela. A dam built there, of the height proposed by the French engineers, would form a lake with a total storage capacity of 14 700 000 000 cu. ft. The greatest deficiency (13 712 000 000 cu. ft.) would require a storage of 660 cu. ft. per second for a period of eight months, making the total average requirements for these eight months 3010 cu. ft. per second. The least discharge for eight months, of which there is any record, occurred in 1899 and averaged 4 340 cu. ft. per second, showing that there is ample margin for evaporation and contingencies.

The last supposition provides for 14 600 passages yearly. Before this number of ships is reached it is probable that the average tonnage

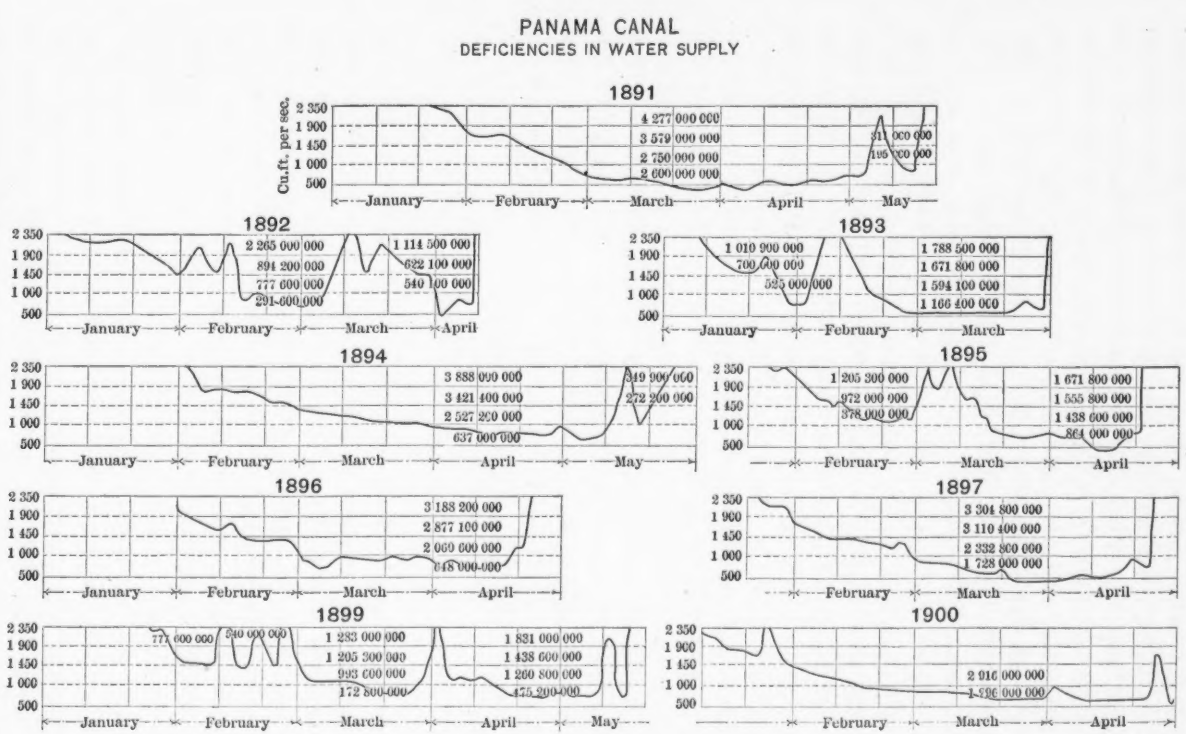

PANAMA CANAL
DEFICIENCIES IN WATER SUPPLY
1891
Cu. ft. per sec.
2 350
1 900
1 450
1 000
500
4 277 000 000
3 579 000 000
2 750 000 000
2 600 000 000
January
February
March
April
May
1892
2 265 000 000
894 200 000
777 000 000
291 600 000
1 114 500 000
622 100 000
540 100 000
January
February
March
April
1893
1 010 900 000
700 000 000
525 000 000
1 788 500 000
1 671 800 000
1 594 100 000
1 166 400 000
January
February
March
1894
3 888 000 000
3 421 400 000
2 527 200 000
637 000 000
349 900 000
272 200 000
January
February
March
April
May
1895
1 205 300 000
972 000 000
578 000 000
1 671 800 000
1 555 800 000
1 438 600 000
864 000 000
February
March
April
1896
3 188 200 000
2 877 100 000
2 069 600 000
648 000 000
January
February
March
April
1897
3 304 800 000
3 110 400 000
2 332 800 000
1 728 000 000
February
March
April
1899
777 600 000
540 000 000
1 233 000 000
1 205 300 000
993 600 000
172 800 000
1 831 000 000
1 438 600 000
1 260 800 000
475 200 000
January
February
March
April
May
1900
2 916 000 000
1 296 000 000
February
March
April

FIG. 2.

will be more than doubled and that this will represent a traffic of from 80 000 000 to 100 000 000 tons annually.

The system now proposed for the control of the Chagres and for the supply of water to the sumit level is entirely automatic, except under two conditions which would very rarely occur. In case of extreme flood, if it is desired to pass any water through the canal, it must be done by opening the lock valves or the gates of a special by-pass. If the Alhajuela Dam is built to make an upper storage reservoir, gates must be opened by which the water will be received from that reservoir; or, if flash-boards are used, those flash-boards must be replaced after floods of exceptional violence, an operation of the very simplest kind. The beauty of the plan recommended is that, in boldly treating the subject as a whole, the annoyance and dangers of detail are avoided.

Culebra Cut.

The term "Culebra Cut" is applied by the French Company to the single mile of cutting of greatest magnitude. As used in this paper it is understood to apply to the entire cut between the Chagres valley and the point where tide water is first reached on the Pacific side, the northern terminus of this cut being at Obispo and the southern terminus at Pedro Miguel, a total distance of nearly 8 miles, of which the southern 2 miles are in a comparatively low country. For 5 miles this cut is really through a mountain, the maximum original height, on the center line of the canal, being 330 ft. above mean tide. While in the upper part of the work where the cut was first opened there is some soft and slippery clay, nearly the whole of this excavation must be made through a material which has generally been rated as rock. It is, in fact, an indurated clay, not firm enough to class as shale, but perhaps quite as hard to work. It is intersected here and there by thin strata and dikes of hard limestone. It is a material which would weather rapidly and go to pieces in a northern climate where there is frost; in the damp warm climate of the Isthmus it does better, but when fragments are immersed in water they fall into powder, and it would evidently be unsafe to expose the unprotected sides of this excavation to the wash of the water in the canal. It was the judgment of the Commission, in which the writer fully concurs, that this cut should be estimated on the basis of slopes of 1 on 1,

which is a little flatter than the slope adopted by the new French Company. This does not mean that the cut would be excavated to those lines. The plan selected by the French Company, consisting of a number of benches connected by comparatively steep slopes, is probably the best way to finish the sides of the cutting, but it was thought that an estimate based on uniform slopes of 1 on 1 would give aggregate results quite as close to the actual work as could be obtained by more complicated calculations; furthermore, it would probably leave a margin to cover such special repairs as may be found necessary where faults and weaknesses appear on the slopes. On the basis of 150 ft. bottom width and slopes of 1 on 1, this cut, 7.95 miles long between Obispo and Pedro Miguel, with the bottom at an elevation of 47 ft. above mean tide, was estimated by the Isthmian Canal Commission to contain 43 237 000 cu. yds. With the depth remaining constant, each foot of increased or decreased width would represent, approximately, 150 000 cu. yds., provision being made for retaining the full width at a passing point, 1 600 ft. long, near the middle of this section. As the side slopes are 1 on 1, the bottom width being constant, each foot that the bottom is raised or lowered would represent an approximate decrease or increase of 300 000 cu. yds., besides the bottom excavation above or below Elevation 47. If the bottom were raised 3 ft., to Elevation 50, it would save 1 600 000 cu. yds., reducing the volume to approximately 41 600 000 cu. yds. If the width of this cut were reduced from 150 to 100 ft., this would represent a further approximate saving of 7 500 000 cu. yds.

On the other hand, if the bottom of the canal were lowered to 35 ft. below mean tide, the bottom width being reduced to 100 ft., reverting to the original de Lesseps scheme for a tide-level canal, the amount of excavation in crossing the divide would be increased to about 85 000 000 cu. yds. While this quantity is enormous, it is not beyond the capacity of a well-conducted work.

The concentration of so large an amount of excavation in so small a distance is without precedent. The engineer will recognize at once that it requires thorough organization, and tools specially adapted to the work. The large plant provided by the old French Company is now from fifteen to twenty years old. Those years have been years of unusual development in this class of machinery. Time is of the utmost importance. The wisest course would be to consign practi-

cally everything which is now on the Isthmus to the scrap heap, and handle this work with the best modern tools that can be obtained; some of these might be tools which could be bought in the market, but many must be specially designed for this particular work. Fortunately, there is ample ground on which to deposit the spoil from this great cut both north and south of the divide, but the manner of conducting the work, both in general principles and in detail, should be thoroughly worked out before actual execution is begun. No work has ever been undertaken on which the highest class of practical engineering talent could produce so great economies as in this particular great concentrated excavation. The Isthmian Canal Commission estimated the cost of this excavation at 80 cents per cubic yard; bad management would quickly raise this to a dollar, and it is not impossible that with a carefully considered equipment the cost could be reduced to 60 cents. In this single cut $25 000 000 is an easy measure of the difference between competent and incompetent management.

As already stated, it is thought unsafe to allow the earth in this cut to be washed by the water of the canal. The French plans have recognized this and have provided for facing the slopes of the canal with masonry. The construction of this cut interferes with the old line of the Panama Railroad. With the canal completed, the railroad will have little value except as a tender to the canal, and its most convenient location would be close to the canal. It is important to provide broad benches between the water of the canal and the slopes of the cut, so that any material which may break loose on the slopes can be stopped and handled before it reaches the water of the canal. It is desirable, if the sides of the canal are lined with masonry, to have this masonry nearly vertical, so that there would be no danger of a ship striking the masonry lining below water. These requirements are met by a special cross-section, which is shown in Fig. 2. The masonry walls may appear unnecessarily expensive, but their function is triple—they protect the slopes from the wash of the water; they accommodate the Panama Railroad; and they provide a bench in case of accident on the slopes. These walls should be provided for a length of 32 000 ft.—about 6 miles. They would contain in the aggregate 1 200 000 cu. yds. of concrete masonry, and their length and cost is practically independent of the elevation of the canal bottom or the width of the canal.

PANAMA CANAL
SECTION AT MILE 34.5

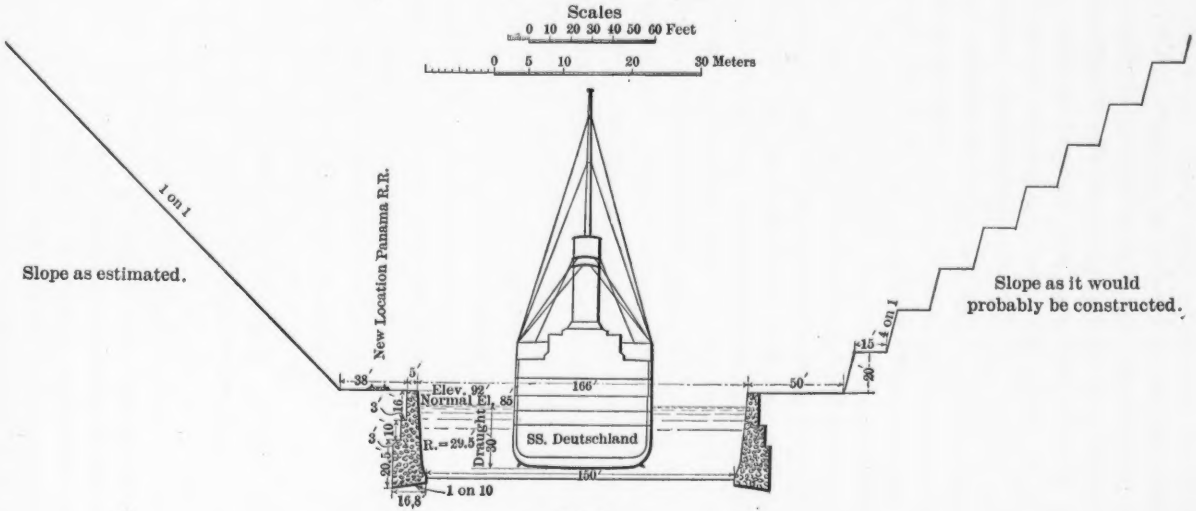


FIG. 3.

Combining these two results and using the price of 80 cents per cubic yard for excavation and $8 per cubic yard for concrete masonry, we have as an approximate estimate of the cost of this cut, with a bottom width of 150 ft. at Elevation 50, $43 000 000. Each foot of increased width will represent an additional cost of $120 000, and each foot that the bottom may be lowered will represent an additional cost of about $400 000.

A tide-level canal 35 ft. deep, with a bottom width of 150 ft. between Obispo and Pedro Miguel, would cost nearly $90 000 000.

Intermediate Levels.

There would be two intermediate levels—a level 5.58 miles long between the Bohio and Tiger Hill locks on the Atlantic side, and a level 1.27 miles long between the Pedro Miguel and the Miraflores locks on the Pacific side.

The former may be designated as the Tiger Hill Level and the latter as the Miraflores Level.

The normal surface of the water in the Tiger Hill Level is at Elevation 26, the bottom of the excavation being at Elevation — 9. This level involves nearly 8 000 000 cu. yds. of excavation, of which about one-third would be rock. Its estimated cost is about $5 000 000. For a portion of the distance the water in the canal is carried above the level of the surrounding country, and it is carried across the bed of the Chagres three times, twice at places where that bed is already abandoned, and once at Bohio, where the river will continue to flow until the discharge of the lake through the Gigante Spillway is accomplished. No complete borings have yet been taken along this line of the canal, but the indications are that no serious trouble is to be expected, the only possibility being leakage, which can be controlled by a moderate amount of puddling.

The normal surface of the water in the Miraflores Level is at Elevation 28, the bottom of the excavation being at Elevation — 7. This level is perfectly straight, and involves only 1 200 000 cu. yds. of excavation, of which one-quarter may be rock. The estimated cost is $800 000. This section is really the deepening of a natural valley, and the surface width of the water will exceed that of the canal proper. A small fixed dam, which will act as a spillway, will be required adjoining the Miraflores Lock.

Maritime Levels.

The Atlantic Maritime Level will be 9.33 miles long, from the 6-fathom contour in Colon Harbor to the Tiger Hill lock, of which seven-tenths of a mile will be outside the terminus of the French Canal. The difficulties of the 35-ft. channel are more marked here than at any other place. Colon Harbor practically lies entirely within the 6-fathom contour, so that the channel has to be extended from the terminus proposed for the French Canal completely through the harbor to deep water. It is probable that a considerable amount of coral rock will be met in excavating this line to deep water, although the exact amount is not known. The cost of the channel outside the terminus of the French Canal, excavated with a bottom width of 500 ft., was estimated by the Isthmian Canal Commission at $1 284 270. This work could be deferred until after the opening of the canal, but it must be done before the largest class of vessels can be accommodated. Very careful and full surveys must be made of this portion of the bay before the best location for this deep-water channel can be determined, and it is possible that it may be found best to cut through the artificial point on which the statue of Christopher Columbus now stands, making the terminus of the canal near the northern end of Colon, at which point some kind of protective breakwater may then be required. The 8.92 miles of canal proper, from the terminus of the French work, opposite the statue of Columbus, to the Tiger Hill lock, would involve an excavation of 14 761 669 cu. yds., this including an allowance for an inshore basin, and is estimated to cost $9 813 000, making the approximate cost of the entire maritime section $11 100 000, of which $1 300 000 can be deferrred until after the opening of the canal.

The Pacific Maritime Section is 8.60 miles long from Miraflores lock to the 6-fathom contour in Panama Bay. Of this, 5.50 miles are canal proper, through a very low country, and the remaining 3.10 miles are open channel, through Panama Bay. This section involves the excavation of nearly 7 000 000 cu. yds., of which about one-fifth would be rock under water—the most expensive kind of excavation—and the remainder hydraulic dredging—the very cheapest kind of excavation. The estimated cost of this level is somewhat less than $8 000 000.

The description already given of the Tide-Level Canal has included the line through to deep water in the Atlantic. On the Pacific side, the

work between the Miraflores lock and the 6-fathom contour would be identical with that of the high-level canal. The Miraflores lock would be required as a tide lock. The Miraflores Level would be lowered 28 ft. The excavation on this level would be, approximately, 2 500 000 cu. yds., at a cost of, approximately, $2 500 000, a portion being rock under water.

Special Structures.

If the tide-level canal were adopted, but two special structures would be required—a tide lock at Miraflores and a dam at Alhajuela, the object of the dam being simply to check the flow of extreme floods, and its construction could be deferred until the completion of the canal. The lock at Miraflores would be fitted with double gates and used strictly as a tide lock. In cases of extreme floods the gates should be kept closed at all times, so as to prevent any undue current through the summit cut. Under ordinary conditions it might be expedient to leave all the gates open when the tide is above mean stage, thus allowing a moderate current to flow from the Pacific to the Atlantic during high tide. The exact working of such a lock would, however, be determined by experience. The approximate cost of the lock and the Alhajuela Dam, including a railroad to the dam site, may be taken at $8 000 000.

On the high-level canal there would be six important constructions, besides five other works of less size. These eleven constructions are as follows:

1.—Bohio Dam;
2.—Gigante Spillway;
3.—Bohio Locks;
4.—Pedro Miguel Locks;
5.—Tiger Hill Lock;
6.—Miraflores Lock;
7.—Obispo Gates;
8.—Tiger Hill Spillway.
9.—Miraflores Spillway;
10.—Diversion Channel near Gatun;
11.—Diversion of Panama Railroad.

Bohio Dam.—The summit level is sustained by the Bohio Dam, although its height is regulated by the Gigante Spillway. The situa-

tion of the dam, about 3 miles away from the spillway, is very important. The functions of the dam are confined to holding back the water, the dam never being exposed to any currents, either above or below, and the only source of danger being wave action and possible infiltration. The plan of dam which the writer prefers is described in the paper on "The Bohio Dam."* Since that time his attention has been called to a form of metallic sheet-piling, designed and used by Mr. George W. Jackson, of Chicago, composed of channels and I-beams, which seems to admit of penetration to very great depths, and may form an inexpensive and available method of absolutely closing the seepage through the valley, should such closure be considered sufficiently important. This arrangement of sheet-piling is shown in Fig. 4.

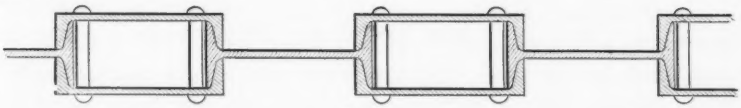


FIG. 4.

Gigante Spillway.—The Gigante Spillway, although a work of considerable magnitude, involves no special difficulties in construction, as rock is found for its entire length above tide-water level. It would be built in the form of a masonry dam with a crest 2 000 ft. long. The estimated cost of this spillway is $1 200 000, this including the excavation for the foundation and such excavation as is necessary to make a clear approach for the water from the lake.

Locks.—There will be four sets of locks, of which two, at Tiger Hill and Miraflores, have a single lift; and two, and Bohio and Pedro Miguel, a double lift. It is proposed to build twin locks in every case, so that an accident to a single lock would not close the canal to traffic. The construction of the second lock would, however, be properly deferred until after the opening of the canal. This arrangement requires twelve lock chambers, in all.

The plan of the French engineers involved sixteen lock chambers, which they estimated to cost 137 000 000 francs, or 8 562 500 francs per chamber—in round numbers, $1 700 000 per lock chamber.

The Isthmian Canal Commission, estimating on the line now recommended, made the cost of the locks $29 189 994, an average of $2 432 500 per lock chamber.

Transactions, Am. Soc. C. E., Vol. xlviii, p. 235.

It is probable that a considerable saving could be made by using metal in combination with the concrete of the locks, but, for present purposes, the estimate of the Isthmian Canal Commission may be accepted, and the cost of the locks given in round numbers as $29 000 000, of which about $17 000 000 would represent the cost of the first set of locks and $12 000 000 the cost of the second or twin locks.

Obispo Gates.—Conditions can be conceived of in which it will be important to draw off the water from the Culebra Cut without disturbing the water in the lake. For this purpose a pair of gates should be placed at the north end of the cut. These gates, if made 100 ft. wide, with the necessary masonry and excavation, are estimated to cost $300 000.

Tiger Hill and Miraflores Spillways.—Two spillways are required, one adjoining the Tiger Hill lock and the other adjoining the Miraflores lock, to take care of excess water in the intermediate levels. These are small affairs, the estimated cost of the two being less than $100 000.

Diversion Channels.—The principal diversion channel required will be that across the peninsula opposite Gatun; this would be a cut of considerable magnitude, and much of it would be through rock. It has been estimated of sufficient size to give a cross-section of 10 000 sq. ft. In addition to this the diversion channel dug along the east side of the canal by the old French Company must be put in order to take the discharge of the Gatun and the various other local streams which would otherwise enter the canal. An allowance of $2 000 000 should be made for these works, nearly all of which will be for the Chagres Diversion.

Diversion of Panama Railroad.—Both tide-level and high-level canals interfere with the Panama Railroad, the latter much more than the former.

For the canal described in this paper, the location of the Panama Railroad will have to be changed for a short distance near Tiger Hill and for the entire distance between Bohio and Obispo, while from Obispo to Pedro Miguel the railroad would be carried through the cut made for the canal. The cost of these changes in the Panama Railroad is estimated at $1 300 000.

The tide-level canal interferes but little with the Panama Railroad;

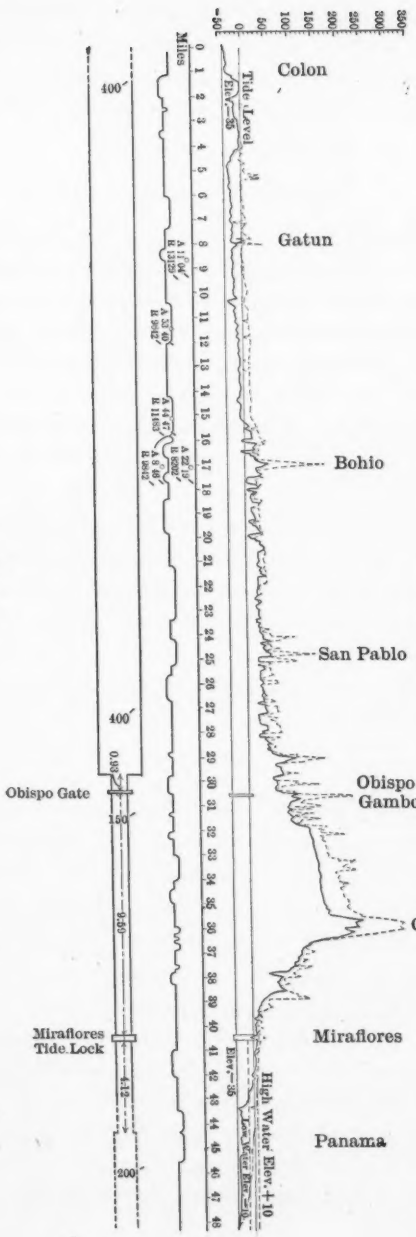

PANAMA CANAL
PROFILE OF TIDE-LEVEL CANAL
Horizontal Scale
Miles
Kilometers
Original ground surface
Drowned channel
Colon
Gatun
Bohio
San Pablo
Obispo Gamboa
Culebra
Miraflores
Panama
Obispo Gate
Miraflores Tide Lock
Tide Level Elev.+10
Elev.+85
Elev.+85
High Water Elev.+10
Low Water Elev.+0
400'
400'
150'
200'
0.89
0.50
412'
Miles

Fig. 5.

but, in order to avoid crossing the canal, a new line of railroad should be constructed from San Pablo to Obispo, about 6 miles, and the railroad should be carried through the cut between Obispo and Pedro Miguel; these changes would probably not cost more than $500 000.

Estimates.

The estimates made in this paper are based on the report of the Isthmian Canal Commission, modified to suit changes in plans. In general, round figures have been taken, as it seems unwise to confuse the memory with a number of small figures, which measure less than the margin of error. By combining the figures already given in detail we have the approximate total cost of the two classes of canals.

To the figures so obtained, an addition has been made of 20% to cover the various incidental expenses and contingencies. The incidental expenses are understood to include engineering, policing and sanitation; in fact, all the expenses on the Isthmus which would not be borne by the contractors. They are not supposed to include any expenses of a home office or of interest during construction. This percentage is double that usually applied in estimating the cost of work in settled countries where risks are not unusual.

Tide-Level Canal.—The cost of a canal on this plan would be approximately as given in Table No. 3.

TABLE No. 3.—Cost of Tide-Level Canal.

Chagres Section, Colon to Obispo	p. 21	$90 000 000
Culebra Section, Obispo to Pedro Miguel	p. 34	90 000 000
Miraflores Section	p. 36	2 500 000
Pacific Maritime Section	p. 35	8 000 000
Miraflores Lock	p. 36	5 000 000
Alhajuela Dam and Railroad	p. 36	3 000 000
Diversion of Panama Railroad	p. 40	500 000
		$199 000 000
Engineering and Contingencies, 20%		39 800 000
Total		$238 800 000

Nearly the entire cost of this canal will be for excavation.

Lock Canal.—The estimated cost of a canal with locks, as described in this paper, the summit level varying from 85 to 90 ft., with three locks on each side, six in all, will be as given in Table No. 4.

TABLE No. 4.—Cost of Lock Canal.

Atlantic Maritime Level, Colon to Tiger Hill	p. 35	$11 100 000	
Tiger Hill Level	p. 34	5 000 000	
Lake Bohio	p. 22	1 000 000	
Culebra Cut	p. 34	43 000 000	
Miraflores Level	p. 34	800 000	
Pacific Maritime Level	p. 35	8 000 000	
			$68 900 000
Bohio Dam	p. 36	$2 000 000	
Gigante Spillway	p. 37	1 200 000	
Locks	p. 37	29 000 000	
Obispo Gates	p. 38	300 000	
Tiger Hill and Miraflores Spillways	p. 38	100 000	
Diversion Channels	p. 38	2 000 000	
Diversion of Panama Railroad	p. 38	1 300 000	
			35 900 000
			$104 800 000
Engineering and Contingencies 20%			20 960 00
Total			$125 760 000

The cost, therefore, of completing the Panama Canal on the lock plan would be about one-half that of completing it on the tide-level plan. This, however, does not tell the whole story. Neglecting the percentages for contingencies, all but $18 000 000 of the $199 000 000 estimated for the tide-level canal is for excavation. Of the $46 000 000 estimated as the cost of the Culebra Cut, in the high-level canal, $9 600 000 is for retaining walls along the sides of the cut; this reduces the cost of excavation to $59 000 000, or approximately three-fifths of the total cost of the canal (percentages still being omitted). In other words, although the cost of the tide-level canal is only about double that of the lock canal, the cost of excavation in the tide-level canal is about three times the cost of excavation in the lock canal. Excavation represents work which must be done entirely on the Isthmus. Much

of the cost of special structures represents material which would be manufactured elsewhere. If it be assumed that one-half the cost of the special structures represents work on the Isthmus, it may be said, in a general way, that four-fifths of the cost of the lock canal and the whole cost of the tide-level canal will represent work on the Isthmus. As the tide-level canal will cost twice as much as the lock canal, the amounts to be expended on the Isthmus for the two canals will be approximately as five is to two. The number of workmen required on the Isthmus, as well as the time required to complete the work, will be determined by these conditions.

The tide-level canal will have to be completed before it can be opened to traffic, the only postponement being in a portion of the cost of the special structures, which is insignificent. The lock canal can be opened with the second set of locks unfinished, and before the channel in Colon Harbor is deepened. This will reduce the expenditures required before opening the canal to about $92 000 000, without the percentage, or to a total of $110 000 000.

These estimates are based on the conditions now existing at the Isthmus, advantage being taken of the work which has been done there by the French and of the Panama Railroad. The work done by the New Panama Canal Company is practically all effective. Much of the work done by the old company is valueless. The canal which was excavated through the low country was taken out with a bottom width of 22 m. and a depth of 9 m., and the material was wasted close to the banks. To construct a canal of the increased dimensions now required will involve rehandling the spoil banks. Furthermore, the plan proposed in this paper would utilize the canal between Gatun and Bohio only as a channel for the Chagres, for which purpose it is of great value. The value of all this work, including the railroad, was estimated by the Isthmian Canal Commission at $40 000 000, which sum the New Panama Canal Company of France, and the official liquidator, representing the shareholders and creditors of the defunct Universal Interoceanic Canal Company, have agreed to accept as the price for which they will deliver everything they now own on the Isthmus, together with their records, maps and other papers. If this is added to the foregoing estimates, the cost of the tide-level canal would be about $280 000 000 and that of the high-level canal $166 000 000, exclusive of interest during construction.

Conduct of Work.

The first thing to do is to clean up the Isthmus, to provide sewers where feasible, and sanitary rules everywhere, to furnish the entire line with good water, of which a great abundance may be had at moderate expense, and to compel the employees on the canal to drink nothing else. This will take at least a year.

The plans made by the New Panama Canal Company were unusually complete for any preliminary work of this kind, but they were for a canal of different dimensions, with many details which would not be acceptable to American builders. The plans and examinations of the Isthmian Canal Commission were made for purposes of comparison and preliminary work rather than for actual construction. The final working designs remain to be made. Specifications must be prepared and all the necessary preliminaries which precede the letting of so great a work completed. Both the home and local organizations must be perfected. Much of this work can be done simultaneously with the sanitary preparations, and will take as long. A year spent in preparation, before the contracts are let, will save time in the end.

After the contracts are awarded, the contractors should be allowed another year to perfect their preparations. This is little enough time to provide for the organization of their forces and the purchase and collection of their machinery, much of which will have to be made after the contracts are awarded.

In two years after the transfer of the French property and the beginning of American occupation, actual construction work should fairly begin. The one greatest single piece of work is the Culebra Cut, and the time required to complete this cut will be the time which it will take to build the canal. All other work should be laid out with reference to this, so that, when it is completed, there will be no unfinished work to delay the opening of the canal.

The bulk of the laborers must be West Indian negroes, from Jamaica and perhaps some other islands. Skilled labor must come from the North, and generally be white. The methods of work should be so designed that the number of skilled workmen shall be as small as possible, and that they shall be protected from rain and sun when at work. It will probably be expedient to use electric power instead of steam as far as possible. A dam at the site of the Alhajuela Dam would furnish the power. If electric shovels could be used

instead of steam shovels, but one skilled man, instead of two, would be required at each shovel, and the heat from the boiler would be avoided. The debilitating influences of the damp, warm climate remain, and a system of furloughs must be arranged which will permit the white employees to recuperate in northern climates at least once a year.

The French companies were private corporations, working with no greater powers than those derived from their concessions. All this will be changed when the work becomes a Government undertaking. The powers of the United States will be those of military occupation, under which a sanitary control and discipline can be exercised, which should remove the greatest difficulties which have hitherto beset the Isthmus of Panama.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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A HIGH-VOLTAGE POWER TRANSMISSION.

By M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E.

To be Presented March 4th, 1903.

Introduction.

In 1891 the Missouri River Commission, United States War Department, completed a survey of the Upper Missouri River, including triangulation, topography, hydrography and check levels. The records of this survey for the first time made available complete engineering information regarding the Upper Missouri River. From Three Forks to a point below Canyon Ferry the field work was under the direction of Mr. G. A. Marr, Assistant Engineer, and was fully reported by the Commission in 1891.* The river was then considered navigable to Three Forks, where the main stream is formed by the confluence of the Madison, Jefferson and Gallatin Rivers. From Three Forks to Canyon Ferry, the present location of the dam, the distance along the channel is about 81 miles. The watershed above Canyon Ferry is about 15 000 sq. miles in extent, comprising large parts of Madison, Beaverhead, Gallatin, Jefferson, Silver Bow, Lewis and Clarke, Meagher, and Broadwater Counties, of Montana, and the Yellowstone

* Annual Report of the Missouri River Commission, being Appendix AAA of the Annual Report of the Chief of Engineers, U. S. A., for 1891.

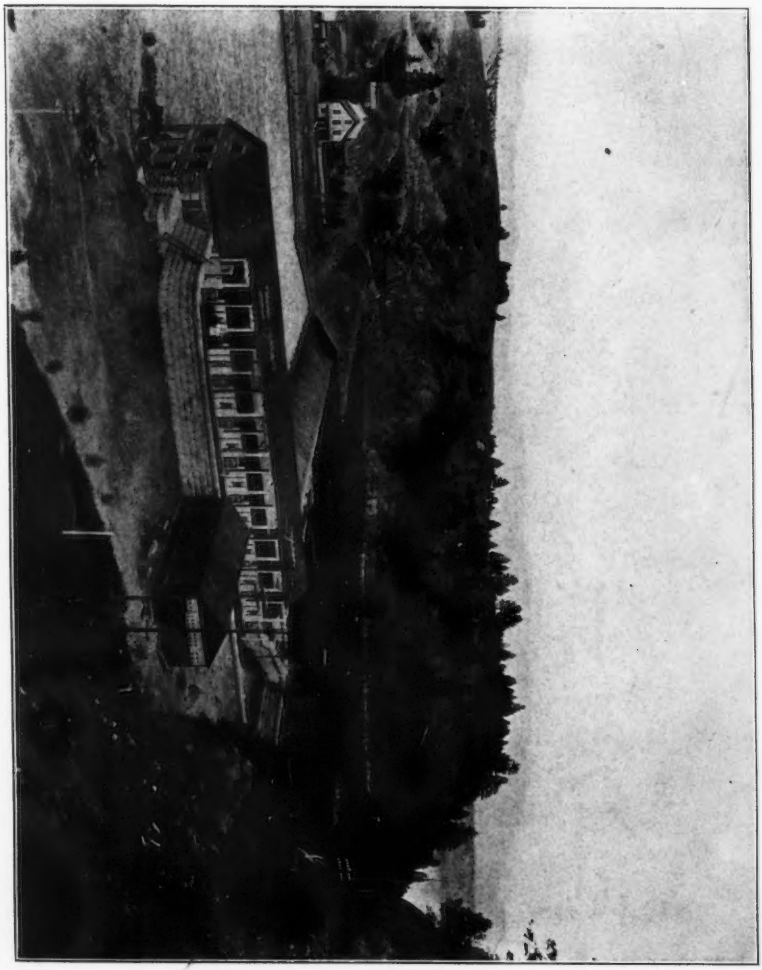
Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

National Park. It is nearly all mountainous country, and embraces slopes of the Big Belt and main range of the Rocky Mountains, as well as a number of smaller ranges.

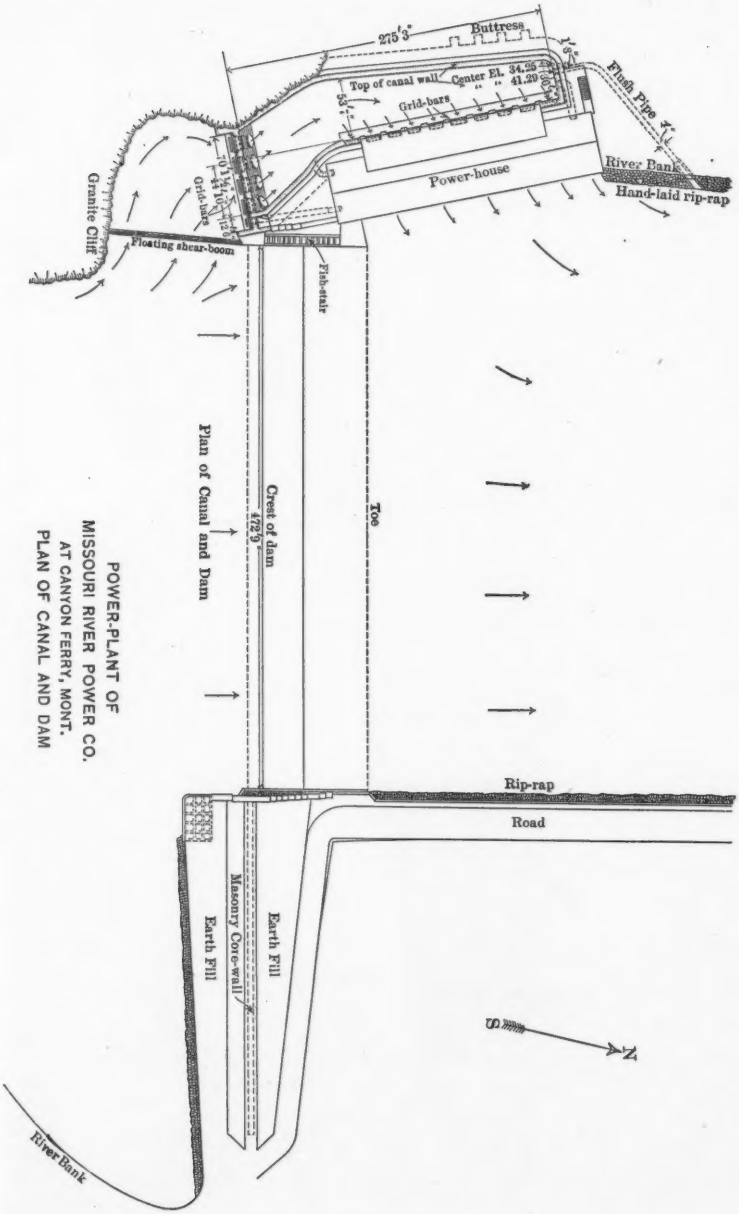
As the result of action by the Board of Trade of the City of Helena, an investigation was ordered by the United States War Department, and a report made on May 10th, 1892, by Captain Charles F. Powell, to the Chief of Engineers, United States Army, pointing out that no regular navigation existed above Great Falls, Montana, and stating that the construction of dams was feasible at a number of points on the Missouri River near Helena. An Act of Congress (approved July 13th, 1892) provided for a more extensive examination of the Missouri River from Three Forks to Canyon Ferry, with a view to determining at what points water-powers could be developed for manufacturing and other purposes. The examination thus authorized was made in 1893 by Mr. Edwin D. Vincent, Assistant Engineer, and the results of his investigation were reported by Captain H. F. Hodges, on January 22d, 1894, to the Chief of Engineers, United States Army. This report contained much valuable information, and indicated, especially, several practicable locations for dams.*

The Helena Water and Electric Power Company was organized, under the laws of the State of Montana, in May, 1896, and work was commenced on the dam at Canyon Ferry the following July, under the direction of Mr. Hugh L. Cooper, Resident Engineer, and J. T. Fanning, M. Am. Soc. C. E., Consulting Engineer. The original intention of the promoters of this enterprise was to supply electrical power and water for manufacturing, private and public purposes, to the City of Helena. About the time the work was begun, Mr. Barton Sewell became General Manager, and Mr. C. W. Whitley, Superintendent. A timber-crib dam, designed by Mr. Fanning, was completed in March, 1898, and the construction of a stone power-house to contain four units, together with the necessary penstocks, gates, etc., was well under way. It was at this time that the property came under the direction of the writer as chief engineer. The plant was completed on the original lines, and consisted of four generating units, each comprising a two-phase alternating-current generator of 750 kilowatts, directly connected to a pair of horizontal water-wheels.

* House of Representatives, Executive Document No. 96, 53d Congress, Second Session, Letter from the Secretary of War, transmitting Report of the Examination of the Missouri River from Three Forks to Canyon Ferry, Montana.

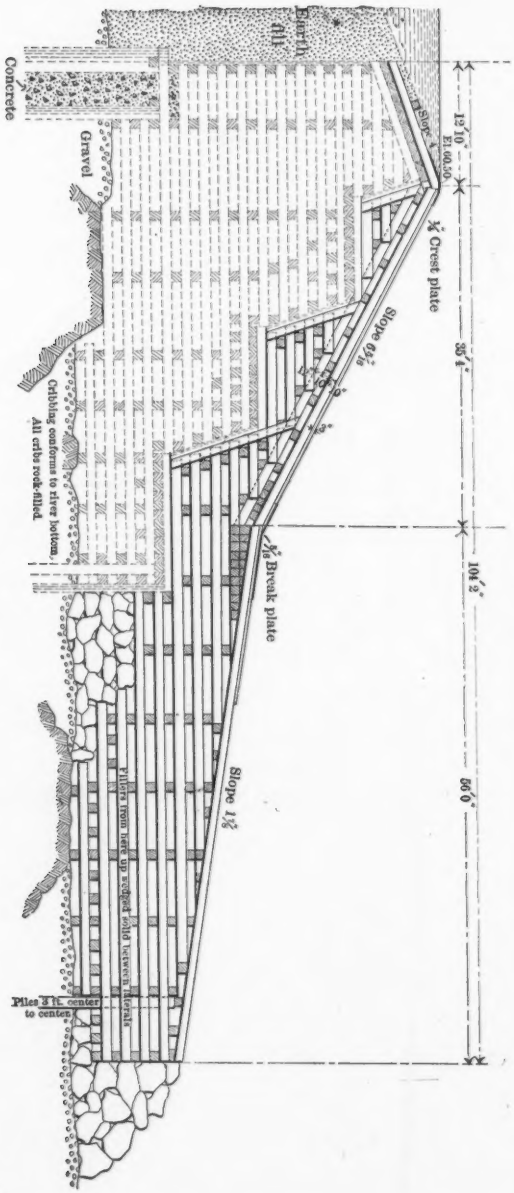


CANYON FERRY DAM, POWER-HOUSE AND CANAL.

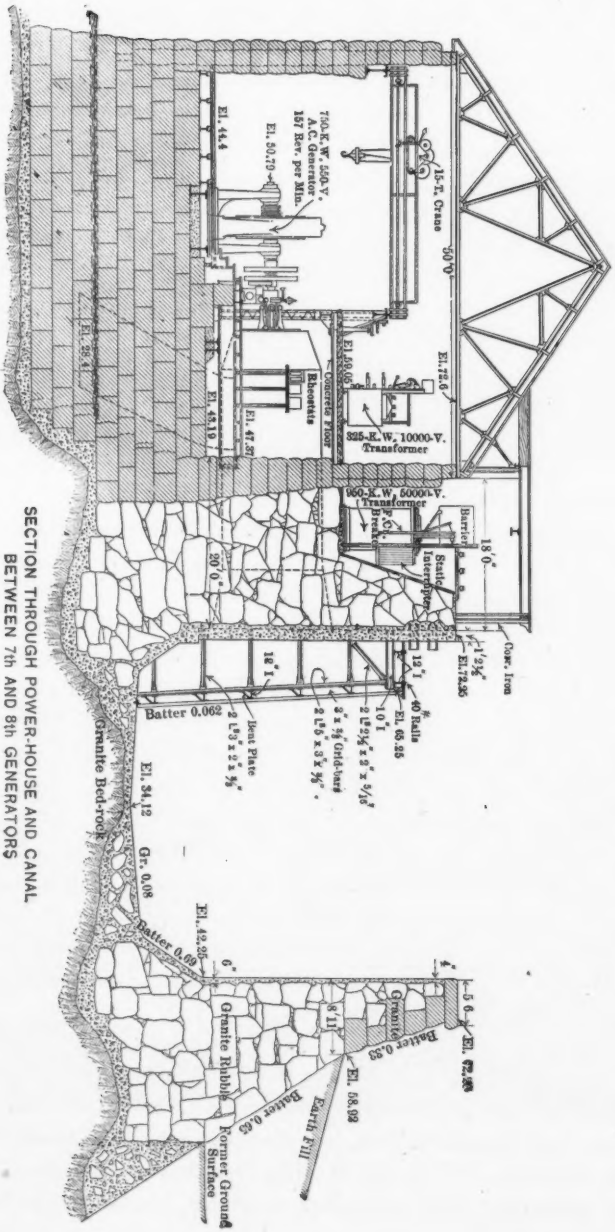


POWER-PLANT OF MISSOURI RIVER POWER CO. AT CANYON FERRY, MONT. PLAN OF CANAL AND DAM

FIG. 1.



CANYON FERRY DAM
AS RECONSTRUCTED
FIG. 2.



SECTION THROUGH POWER-HOUSE AND CANAL BETWEEN 7th AND 8th GENERATORS

FIG. 3.

Water was supplied to the wheels through two steel penstocks, 12 ft. in diameter, from a forebay excavated in the solid rock above the dam.

In May, 1898, shortly after the completion of the dam, and before the remainder of the plant was ready for service, the dam was damaged to some extent by extreme high water. It was immediately repaired and reconstructed on somewhat different lines, and since then has given no trouble. A complete electrical transmission system, operating at 12 000 volts, was installed, and a pole-line constructed to Helena by way of East Helena, together with several branch lines to near-by points. The plant went into regular service in October, 1898, supplying, from the first, three large customers: The East Helena Smelter (now the property of the American Smelting and Refining Company), the Peck Concentrating Plant (the property of the Helena and Livingston Smelting and Reduction Company), and the Helena Electric Lighting and Street Railway Company (now the property of the Helena Light and Traction Company).

The market for power at Helena and vicinity not being sufficient, it was decided in 1900 to enlarge the plant, and construct transmission lines to the City of Butte. To accomplish this result, the company was reorganized as the Missouri River Power Company, a New Jersey corporation, with the writer as Chief Engineer and General Manager. In connection with the enlargement of the plant, it was considered advisable to reconstruct and rearrange the entire plant, both in its hydraulic and electrical elements. In this paper a brief description of the various details of the reconstructed plant has been attempted; and it is thought that some interest may attach to certain of the hydraulic arrangements, and perhaps more especially to the electrical details of the 50 000-volt transmission system to Butte. It should be remembered that this plant was not designed originally for its present service, and that in its reconstruction many arrangements were necessary that would have been changed materially had an entirely new plant been built.

The Generating Plant.

The generating plant is located at the mouth of the Black Rock Cañon of the Missouri River, near the Canyon Ferry post-office, which is 17 miles from Helena and 65 miles from Butte. The works consist of an earth dam, with a masonry core-wall, located on the east side



FIG. 1.—CANYON FERRY DAM AND POWER-HOUSE, LOOKING UP-STREAM.

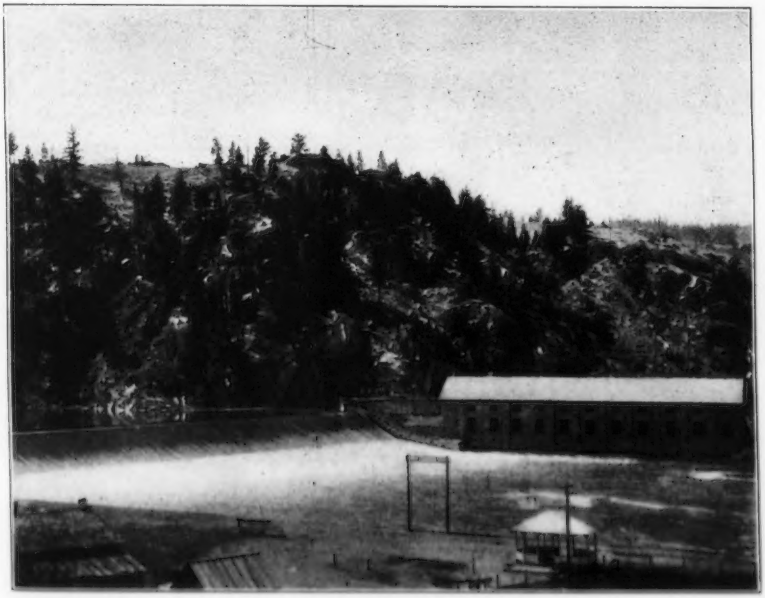


FIG. 2.—CANYON FERRY DAM AND POWER-HOUSE.

FIG. 4.

FIG. 5.

FIG. 6.

DETAILS OF GRID-BARS, GATES, SEALS, ETC.

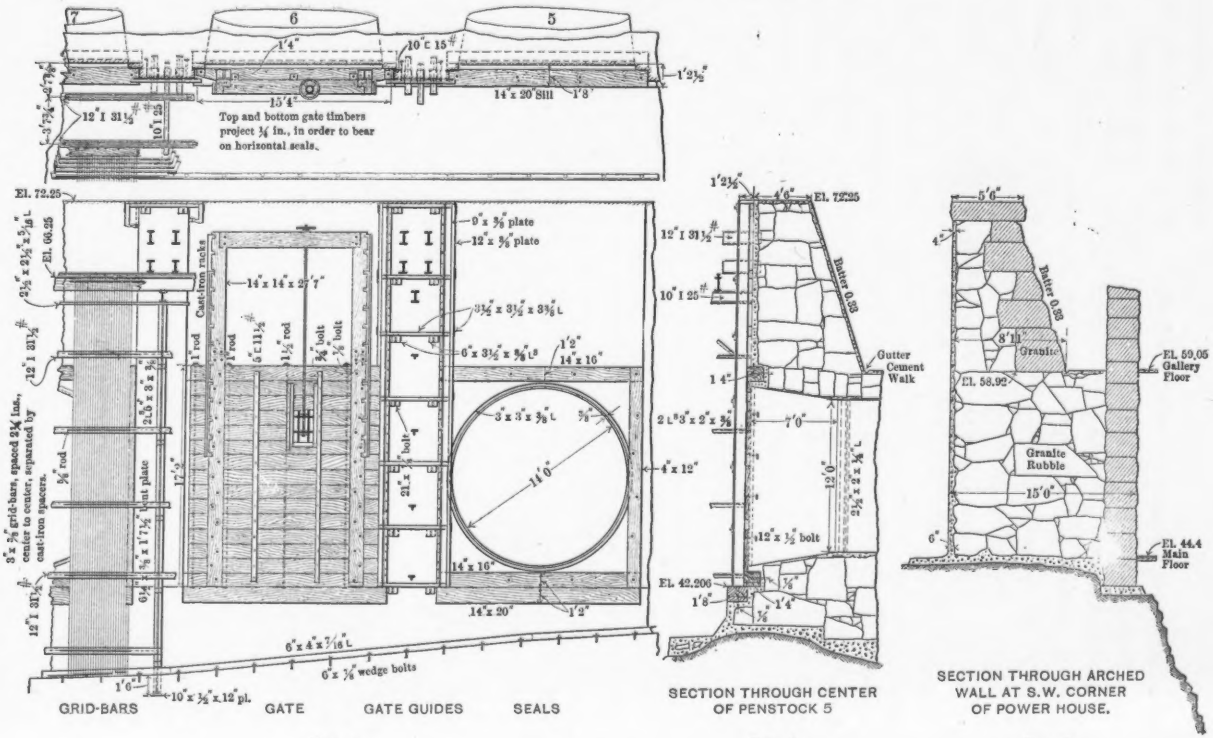


FIG. 4.

FIG. 5.

FIG. 6.

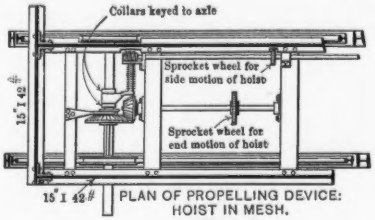
of the river, a timber-crib dam, with masonry abutments, a masonry bulkhead having canal gates, a masonry canal, and a stone power-house. From the east bank to the abutment the distance is approximately 325 ft.; between the abutments is a clear spillway of 472 ft. 9 ins., and fish-stairs 12 ft. in width; and from the west abutment the masonry bulkhead extends 90 ft. to a nearly vertical granite cliff. The total distance from bank to bank on the line of the dam is approximately 900 ft.

Fig. 1 is a general plan of the works; Plate III is a general view of the dam, power-house and canal; Fig. 2 is a section of the timber-crib dam, in its present condition, midway between abutments. The foundations of the power-house, canal walls and west abutment are on granite bed-rock, but in the middle of the stream the bed-rock is found only at exceedingly great depth, the cañon being in the nature of a fissure, or crack, in which the river has deposited silt and gravel. That part of the dam between abutments is a timber crib, rock-filled, and the drawing shows clearly its design, both before and after reconstruction. The dam forms a lake, or reservoir, 7 miles in length and more than 6 sq. miles in area. Fig. 1, Plate IV, is a general view of the dam and power-house, looking up stream from the wagon bridge, which is about 800 ft. below. Fig. 2, Plate IV, is a view from the east side of the river, and shows the power-house and the walls of the cañon.

The four pair of water-wheels received their water originally through two penstocks, but these were removed and a massive stone forebay, or canal, constructed. The dimensions of this canal are given in plan, in Fig. 1. Fig. 1, Plate V, is a general view of this canal, showing the water-wheel head-gates and the west side of the power-house. Fig. 2, Plate V, shows the canal, racks, gates and gate-lifting car. Fig. 3 is a sectional drawing through the canal and power-house, and Plate VI is a plan of the power-house and transformer-room. Figs. 5 and 6 are typical sections through the wall of the canal. The entire canal is of heavy, granite-rubble masonry, with the exception of a few courses on the outside of the wall, as shown. The canal is lined throughout, including the bottom, with Portland cement concrete.

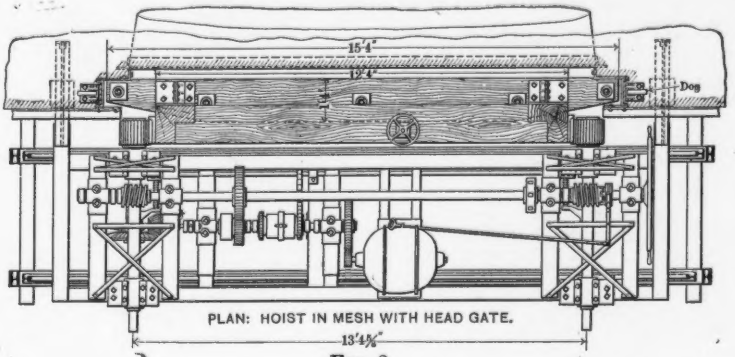
The wheel-cases are of $\frac{5}{16}$-in. steel, 12 ft. in diameter, having conical bell-openings 14 ft. in diameter. These cases are set in the masonry, imbedded in concrete.

ELECTRIC GATE-HOIST.



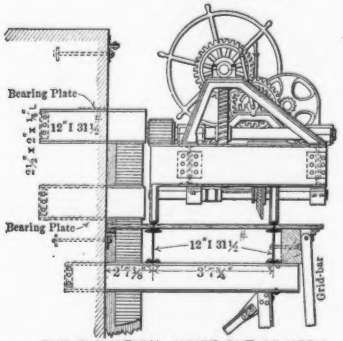
PLAN OF PROPELLING DEVICE: HOIST IN MESH.

FIG. 7



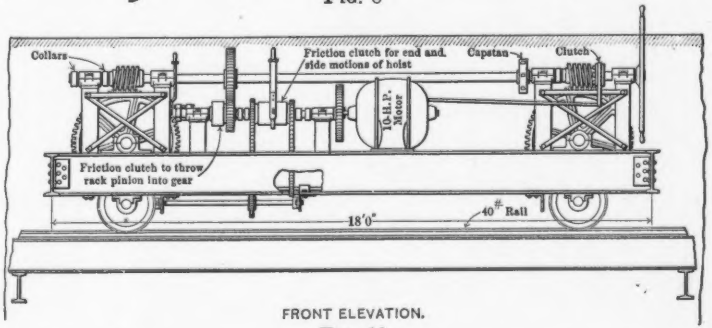
PLAN: HOIST IN MESH WITH HEAD GATE.

FIG. 8



END ELEVATION: HOIST OUT OF MESH.

FIG. 9



FRONT ELEVATION.

FIG. 10

The main gates are ten in number, 15 ft. 4 ins. in width and 17 ft. 10 ins. in height, of Oregon fir, 16 ins. thick in the center. The gates slide in structural-steel guides built in the masonry.

The grid-bars are 3 x $\frac{3}{8}$-in. steel, spaced $2\frac{1}{4}$ ins. from center to center. They are supported by a structural-steel frame, which also carries the rails for the gate-operating car. The construction of the gates, guides, seals and grid-bars is shown clearly in Fig. 2, Plate V, and Figs. 3, 4, 5 and 6. The arrangement for operating the gates is shown in Figs. 7, 8, 9 and 10. This device consists essentially of a car, with the necessary mechanism, traveling on rails parallel to the east wall of the canal, in front of the gates. The rails on which the car travels support it only when moving between gates, or when moving its pinions into or out of mesh with the racks on the gate-lifting bars. The car receives its power, for all its movements and for operating the gates, from a 10-H.-P. direct-current motor, supplied with current from a trolley. The various motions of the car, and the lifting mechanism, are controlled by clutches operated by levers from a centrally located platform on the car. When the pinions are in mesh and the gates are being operated, the entire thrust is carried directly to the masonry, through 12-in. I-beams set in the wall, as shown in Figs. 8 and 9. The various details of the construction are shown clearly in the drawings referred to.

The power-house building is of granite masonry, 228 ft. 3 ins. in length and 50 ft. in width. A gallery, 18 ft. in width, extends the entire length of the building on the west side; and, at the same floor elevation as the gallery, located between the main power-house and the east wall of the canal, is a transformer-room 154 ft. in length. The general construction of the power-house is shown in Fig. 3 and in Plate VI. The building is entirely of masonry and steel, with the exception of the roof and main floor. The roof-trusses are of steel, and the roof is covered on the outside with corrugated iron. The gallery floor is of steel and concrete construction, and the walls of the house are in the natural stone. All the masonry, including the power-house, canal walls, abutments, and core-walls, is of gray granite, quarried and cut on the premises. Portland cement, of both American and European brands, was used throughout.

There are ten pair of water-wheels driving the main generators, two single wheels and one pair of smaller wheels driving the exciters.

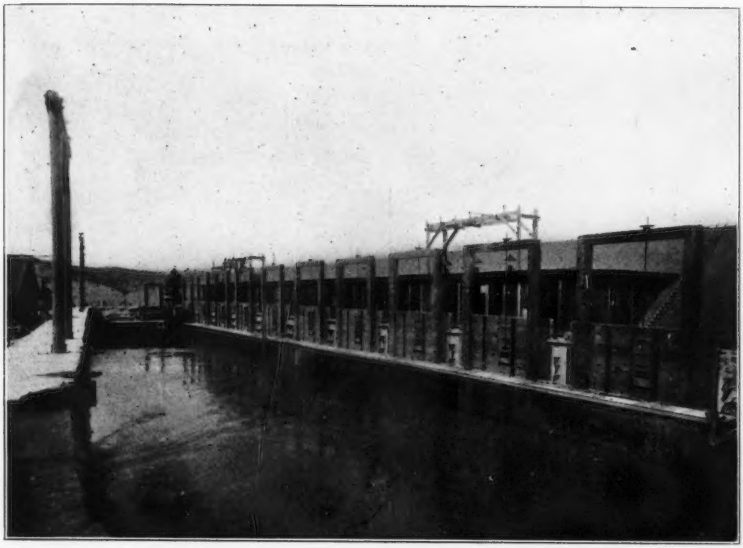


FIG. 1.—CANAL, HEAD GATES AND WEST SIDE OF CANYON FERRY POWER-HOUSE.

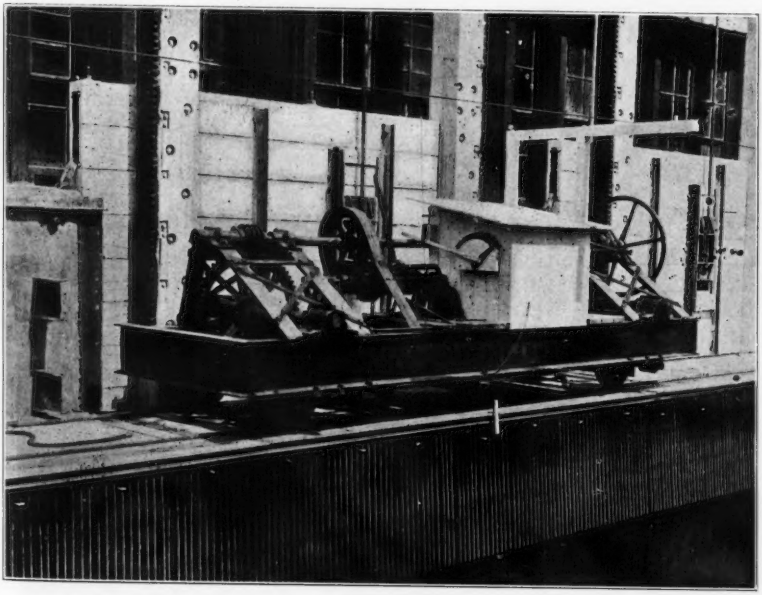


FIG. 2.—GATE-LIFTING CAR.

P

Fig. 11.

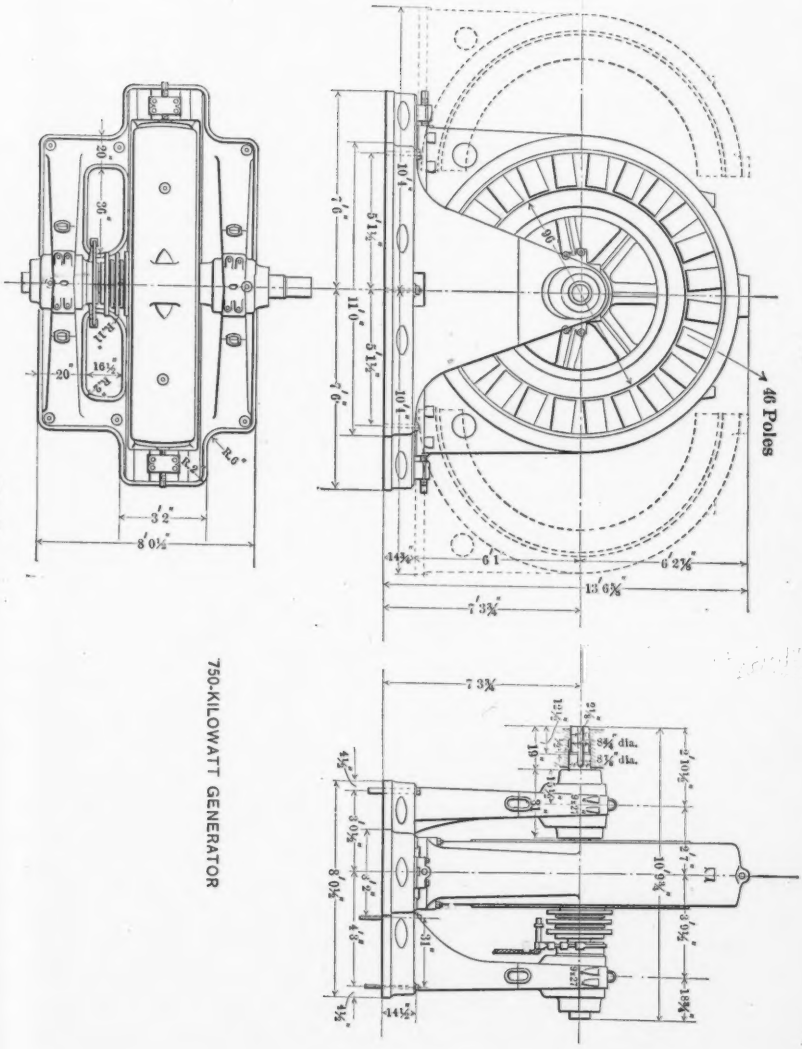


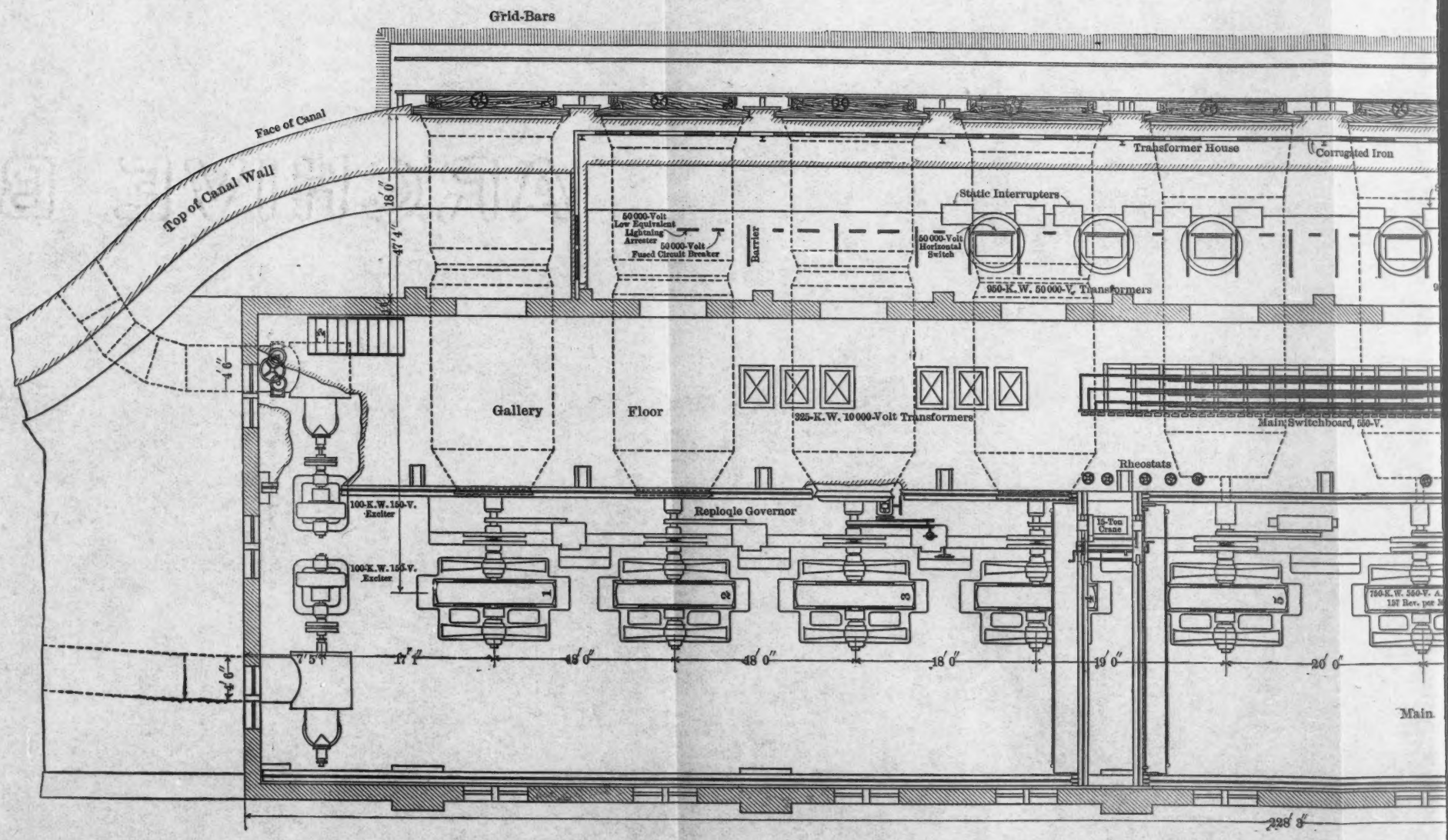
Fig. 11.

The wheels in the old plant are of the "New American" type, and all the new wheels are of the "McCormick" type, manufactured by the S. Morgan Smith Company. Plate VII shows a section through one of the new wheel settings. These wheels have 45-in. runners, and cylinder gates operated by draw-rods through the front head. Outside of the case, attached to the draw-rods, are racks which mesh with the gears operated by the governors. The wheels first discharge the water into central cast-iron draft-chests, then through elliptical draft-tubes into the tail-race. There are two water-bearings on each shaft, one at the outside of the wheel nearest the canal, and the other inside the draft-chest. A third bearing, of a ring-oiling type, is located entirely outside the wheel case and next to the generator coupling. This bearing is also designed to take the thrust in a direction parallel to the shaft, and for that purpose has on the shaft two solid projecting rings, which fit into grooves in the surface of the bearing. Fig. 1, Plate VIII, shows the front head of No. 10 water-wheel, together with the governor and the generator. It also shows two of the exciters, one coupled to a pair of 24-in. McCormick water-wheels, and the other to an induction motor.

The governors in operation are of the "Lombard" type, and this apparatus is too well known to require description other than that the connections between the governors and the water-wheel gate mechanism are made through cut bevel and spur gearing.

The generators have revolving armatures, and are designed to deliver alternating current at three-phase, 60 cycles and 550 volts. The speed is 157 revolutions per minute. Each machine has a rated capacity, in electrical output, of 750 kilowatts at 80% power-factor. The four generators installed originally were two-phase, but they have been rebuilt and converted into three-phase machines. Fig. 11 is a general drawing of one of the new machines. The generators are excited separately by four 150-volt exciters, three of which are driven directly by water-wheels, and one by an induction motor, as previously stated. The connections between the generators and exciters and their water-wheels are made by means of flexible couplings, consisting of cast-iron discs united through rawhide drag-links. The generators and exciters are all of standard types, manufactured by the Westinghouse Electric and Manufacturing Company. A general view of the interior of the station is shown in Fig. 2, Plate VIII, which also gives a good

PLAN OF POWER HOUSE



PLAN OF POWER HOUSE

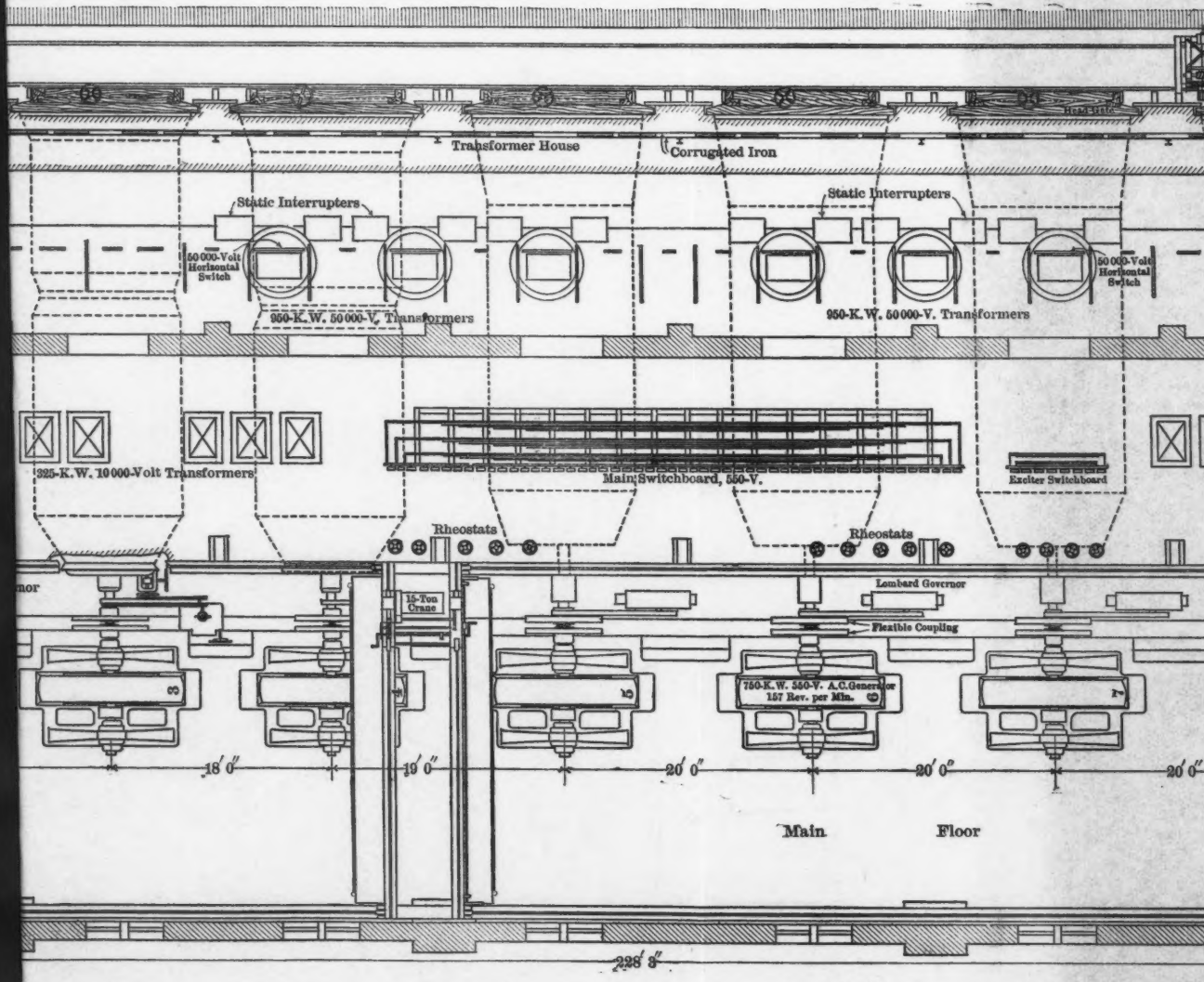
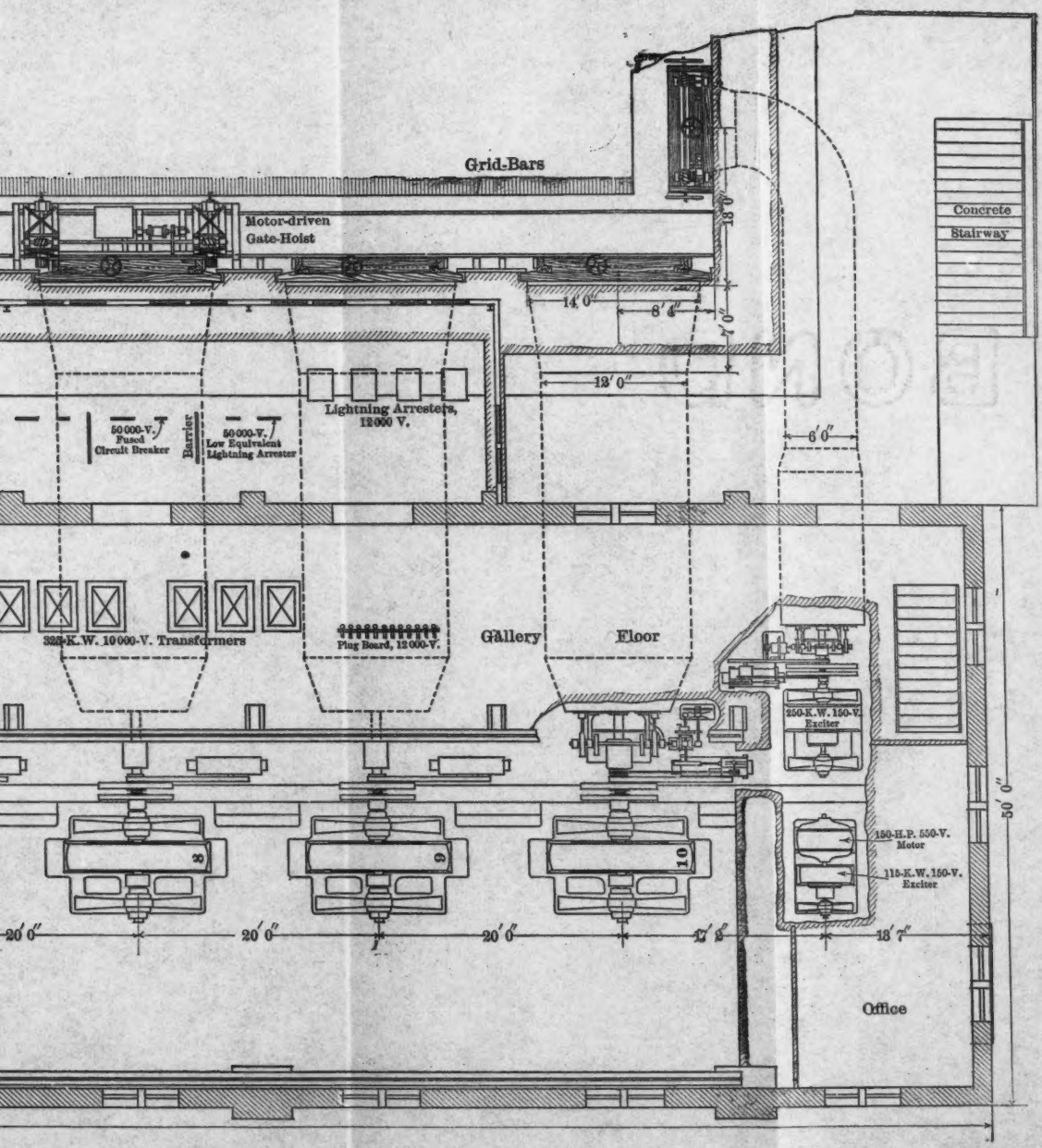


PLATE VI.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
GERRY ON POWER TRANSMISSION.



idea of the mechanical design of the generators and the arrangements in the station.

The switchboards, of blue Vermont marble, are located on the gallery floor in the center of the station. There are seventeen panels in the main board, four in the exciter-board, and four in the 12 000-volt plug-board. Fig. 12 is a general drawing of the main switchboard, and Fig. 1, Plate IX, is a general view of the same board, as installed. The main board consists of ten generator panels, four feeder panels for the 12 000-volt service, two feeder panels for the 50 000-volt service, and one main junction panel in the middle of the board. There are three sets of main bus-bars, extending the entire length of the board, capable of being separated electrically in the middle by means of switches on the junction panel. In the arrangement of the board, starting at one end, are five generator panels, two feeder panels for the 12 000-volt service, one feeder panel for the 50 000-volt service, and the junction panel. On the other side of the junction panel the same number of feeder and generator panels is arranged in reverse order, so that all the feeder panels are grouped together in the center of the board, with the generator panels at the ends. By opening the switches on the junction panel, the board is divided electrically into two independent sections, either of which may be shut down for repairs while the other is in service. Each generator panel is provided with circuit-breakers, a polyphase wattmeter, an ammeter, and three sets of lever switches. Each feeder panel is provided with circuit-breakers, three ammeters, and three sets of lever switches. The junction panel has three sets of lever switches, and six polyphase wattmeters, one for each main circuit. The generator field switches and the integrating wattmeters for the feeders are mounted on small marble slabs, secured to the girder supporting the traveling crane, and are directly in front of the main board. The rheostats are mounted under the gallery floor, and are controlled by hand-wheels on pedestals, which are in front of their respective generator panels. Fig. 13 is a drawing of the exciter board, which is of the same general appearance as the main board. It has two separate sets of bus-bars, and each panel has circuit-breakers, a voltmeter, an ammeter, and two sets of lever switches.

There are twelve transformers, of 330 kilowatts each, for the 12 000-volt service. These transformers are oil-insulated, air-cooled, and are

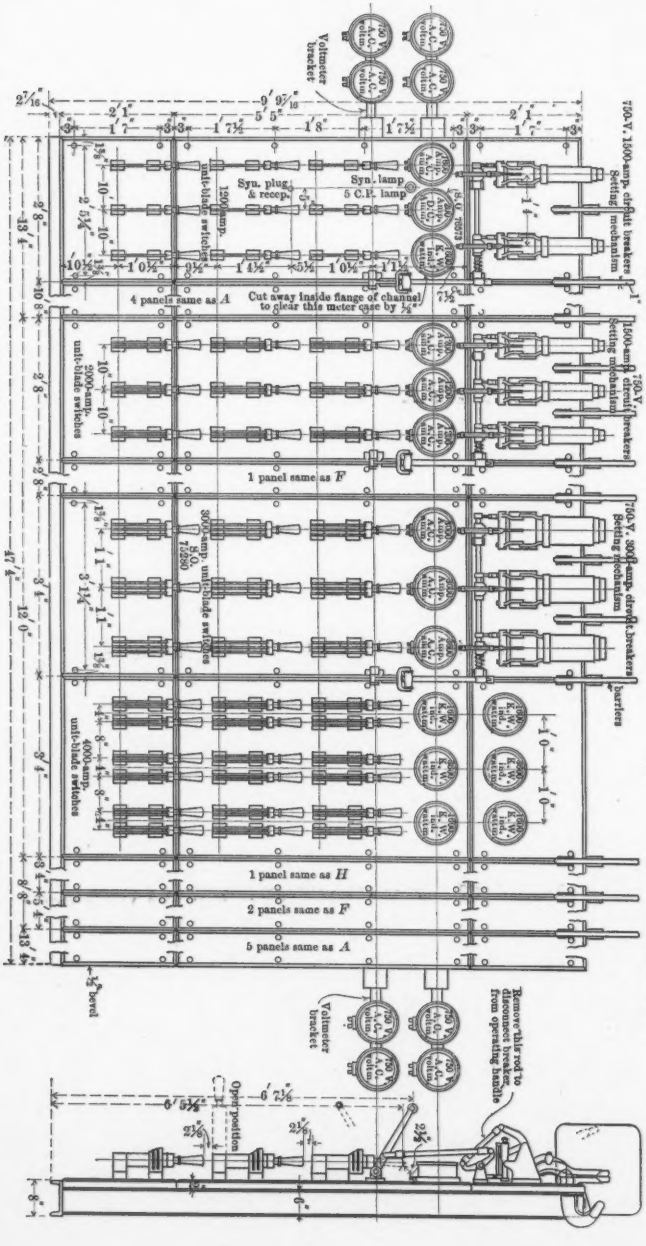

A
B C D E
F
G
H
I
J K L M N O P Q
Voltmeter bracket
750-V. 1500-amp. circuit breakers
Setting mechanism
Syn. plug & recep.
Syn. lamp
5 C.P. lamp
1200-amp. unit-blade switches
4 panels same as A
Cut away inside flange of channel to clear this meter case by ¼"
2000-amp. unit-blade switches
1 panel same as F
750-V. 3000-amp. circuit breakers
Setting mechanism
3000-amp. unit-blade switches
barriers
4000-amp. unit-blade switches
1 panel same as H
2 panels same as F
5 panels same as A
¾" bevel
Voltmeter bracket
Remove this rod to disconnect breaker from operating handle
Open position

FIG. 12.

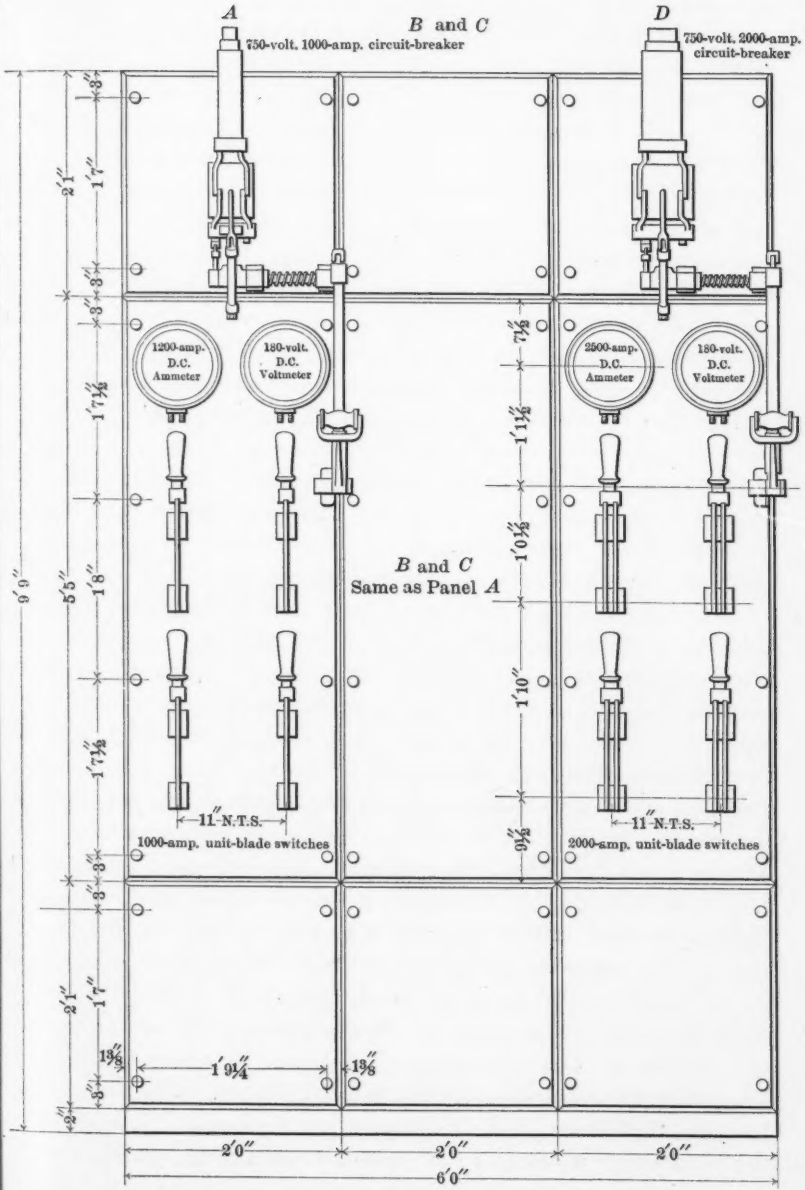
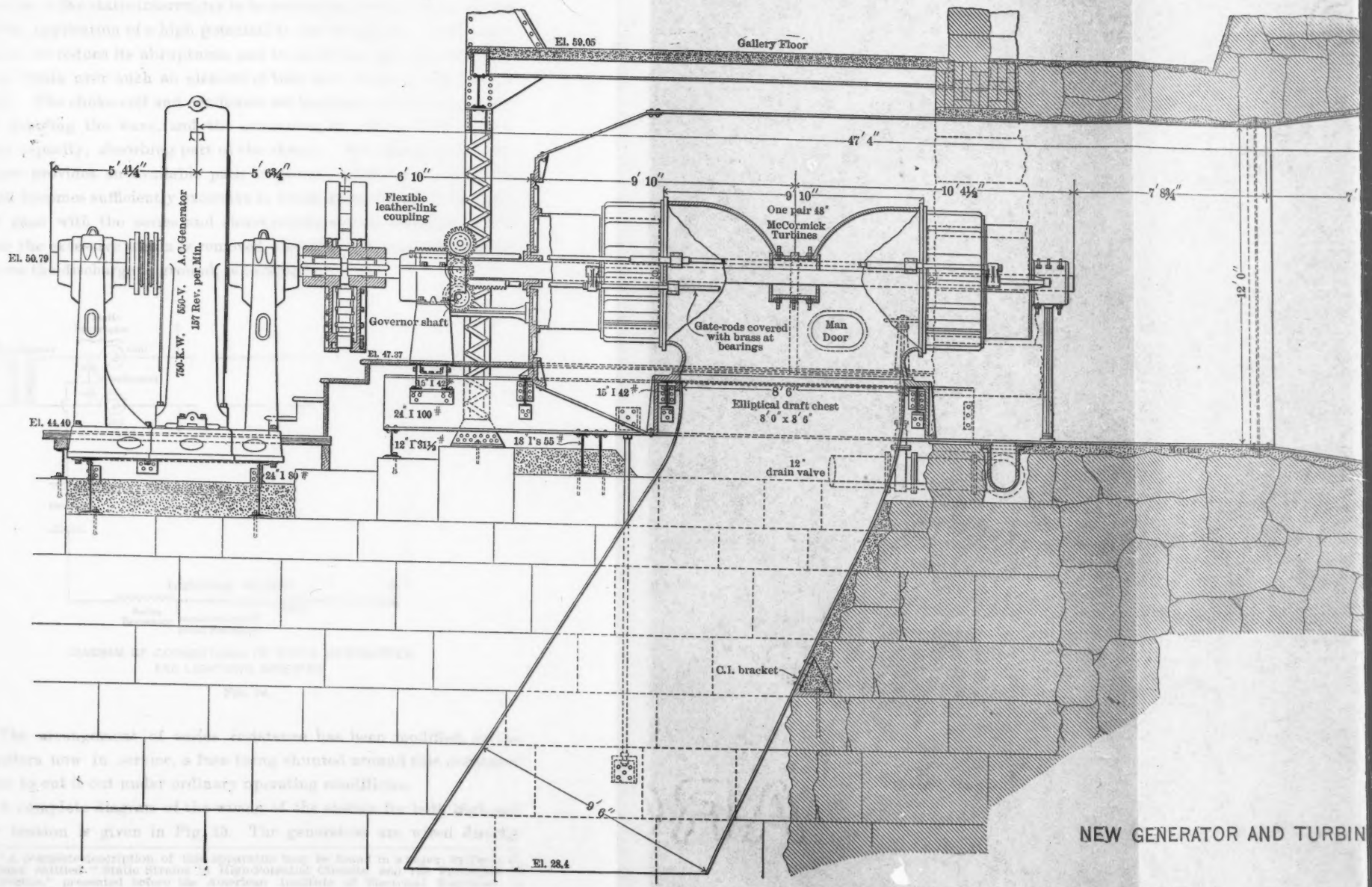

A
B and C
750-volt. 1000-amp. circuit-breaker
D
750-volt. 2000-amp. circuit-breaker
1200-amp. D.C. Ammeter
180-volt. D.C. Voltmeter
2500-amp. D.C. Ammeter
180-volt. D.C. Voltmeter
B and C
Same as Panel A
11″ N.T.S.
1000-amp. unit-blade switches
11″ N.T.S.
2000-amp. unit-blade switches
9′ 9″
5′ 5″
2′ 1″
1′ 7″
1′ 8″
1′ 7½″
1′ 7½″
3″
3″
3″
3″
7½″
1′ 1½″
1′ 0½″
1′ 10″
9½″
1⅜″
1′ 9¼″
1⅜″
2′ 0″
2′ 0″
2′ 0″
6′ 0″

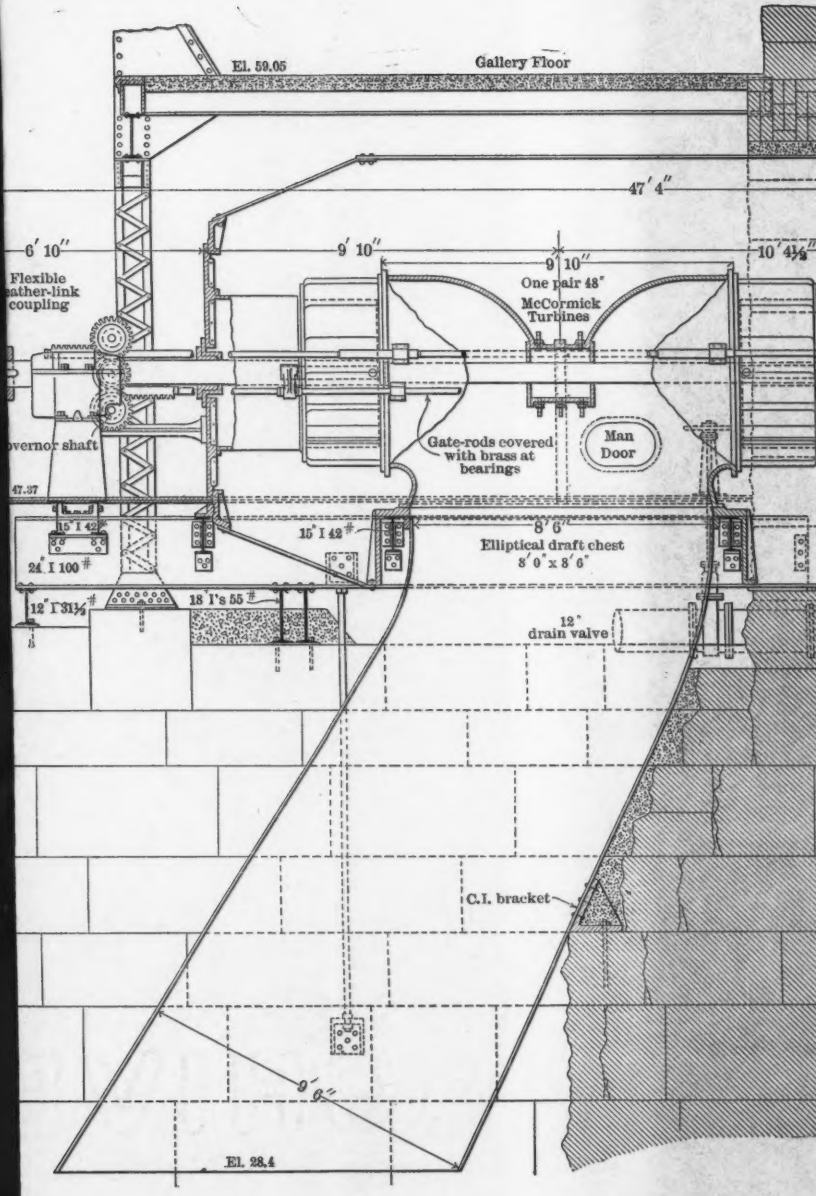
FIG. 13.

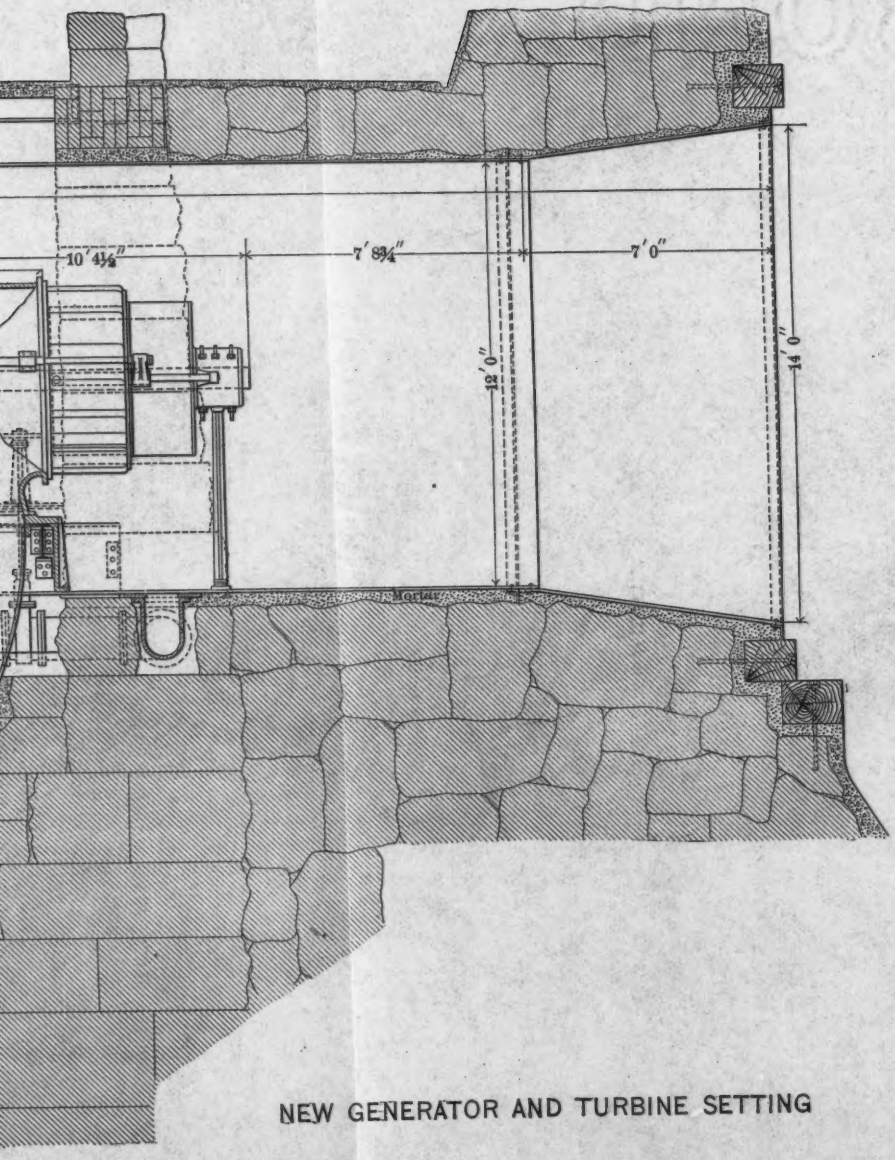
arranged in four groups for three-phase delta connection. They are placed on the gallery floor, six transformers at each end of the switchboard. For the 50 000-volt service, there are six transformers of 950 kilowatts each. These transformers are oil-insulated, water-cooled, are arranged in two groups for delta connection, and are placed in the transformer-room between the wall of the power-house and the east wall of the canal. The 50 000-volt transformers are in heavy, boiler-iron tanks filled with a petroleum oil, and are cooled by means of brass pipes, immersed in the oil, through which circulates water from the canal. As the cooling coils are at an elevation which at times is above the water in the canal, the piping is arranged, by means of by-pass valves, so that the system can be filled and the water siphoned through the coils, discharging through draft-tubes extending below the level of the tail-race. A good head is secured by this arrangement, and the circulation of the cooling water is excellent. Gauges for measuring the flow of the cooling water, and thermometers for measuring the temperature of the oil and water, are on the transformers. Fig. 1, Plate X, is an end view of the 50 000-volt transformer-room, showing the transformers in position.

For the protection of the 12 000-volt service from lightning, standard type, "R," Wurts, lightning arresters are used. These consist of choke-coils and gaps, arranged so as to afford a multiple path to ground. As this apparatus is very well known, no detailed description need be given. For the protection of the 50 000-volt service from lightning, new apparatus has been designed. This consists essentially of two parts, the static interrupters and the lightning arresters proper. The static interrupters, so-called, consist of choke-coils and electrical condensers of small capacity. These coils and the condensers, immersed in a tank containing oil, constitute the static interrupters. Each lightning arrester contains 114 units of six gaps, about $\frac{1}{32}$ in. in width, and one large adjustable gap next to the line. The units are mounted on the face of marble panels, and around part of the units is shunted a resistance; and, in series with all the gaps, between line and ground, is a resistance. The connections of the static interrupters and lightning arresters are given diagramatically in Fig. 14. It will be seen that the choke-coils of the interrupter are connected in series with the transformer windings to be protected, and that the condenser is connected between the transformer terminal and the ground. The



NEW GENERATOR AND TURBIN


El. 59.05
Gallery Floor
47′ 4″
6′ 10″
9′ 10″
9′ 10″
10′ 4½″
Flexible
eather-link
coupling
One pair 48″
McCormick
Turbines
overnor shaft
Gate-rods covered
with brass at
bearings
Man
Door
47.37
15″ I 42#
15″ I 42#
8′ 6″
Elliptical draft chest
8′ 0″ x 8′ 6″
24″ I 100#
12″ I 31½#
18″ I's 55#
12″
drain valve
C.I. bracket
9′ 6″
El. 28.4



NEW GENERATOR AND TURBINE SETTING

function of the static interrupter is to receive the shock caused by the sudden application of a high potential to the terminals of the transformer, to reduce its abruptness, and to distribute the excessive electrical strain over such an element of time as to render it harmless in effect. The choke-coil and condenser act together, in this respect, the coil delaying the wave, and the condenser, by reason of its electrostatic capacity, absorbing part of the charge. The lightning arrester proper provides an available path to ground whenever the electrical strain becomes sufficiently excessive to break down the air in the gaps. The gaps with the series and shunt resistances are arranged so that when the excessive strain is removed, the power current, which often follows the discharge to ground, is broken.*

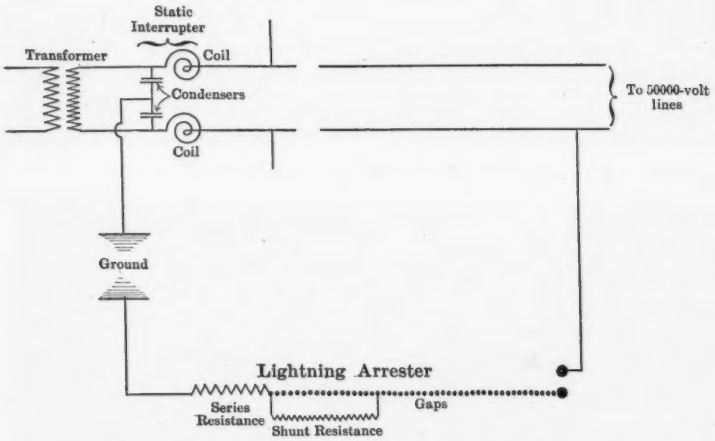


DIAGRAM OF CONNECTIONS OF STATIC INTERRUPTER AND LIGHTNING ARRESTER.

FIG. 14.

The arrangement of series resistance has been modified, on the arresters now in service, a fuse being shunted around this resistance so as to cut it out under ordinary operating conditions.

A complete diagram of the wiring of the station for both high and low tension is given in Fig. 15. The generators are wired directly

* A complete description of this apparatus may be found in a paper, by Percy H. Thomas, entitled "Static Strains in High-Potential Circuits, and the Protection of Apparatus," presented before the American Institute of Electrical Engineers, in February, 1902.

to their respective panels on the switchboard. At the switchboard two of the legs of each generator circuit pass through circuit-breakers, and all three of the legs are connected with three sets of single-pole knife-switches. Each set of knife-switches, upon being closed, connects the three legs of each generator circuit with a set of bus-bars at the back of the switchboard. There are three sets of such bus-bars, and any generator may be connected with any one or all. After passing to the bus-bars the current is first conducted through the switches and the circuit-breakers on the feeder panels, then to the transformers. Especial attention is directed to the arrangement of the switches, circuit-breakers, and instruments, in this part of the wiring.

The current from the 12 000-volt transformers passes to the four-circuit plug-board, which is arranged so that any one of the four circuits may be connected with any one set of transformers, or any number of sets of transformers may be joined to any of the lines, either singly or in multiple. After leaving the plug-board the 12 000-volt current passes through lightning arresters and then to the circuits extending to Helena and adjacent points.

From the six 50 000-volt transformers the current passes through static interrupters and high-tension switches, and is then united by a delta connection, after which it passes through a set of high-tension line-switches to the circuits extending to Butte. The lightning arresters, proper, are connected with each leg of these circuits just before leaving the building. Between the two 50 000-volt circuits are high-tension switches, arranged so that both sets of transformers may be operated together, either on one or both lines; or both lines may be operated from one set of transformers. The arrangement of switches, also, is such that any transformer may be put into or out of service at any time, without interfering with the operation of the plant. All the 50 000-volt main wiring is of 1 000 000 or 800 000-circular mil cable, insulated with rubber, and protected with a lead sheath. The 12 000-volt wiring is No. 4, solid copper, insulated with $\frac{5}{16}$-in. pure para rubber, covered with double cotton braiding, and is supported on porcelain line-insulators. The 50 000-volt wiring is of No. 4 copper, having an insulation of $\frac{7}{16}$-in. pure para rubber, protected with double cotton braiding, and is supported on the regular, glass, line-insulators and pins.

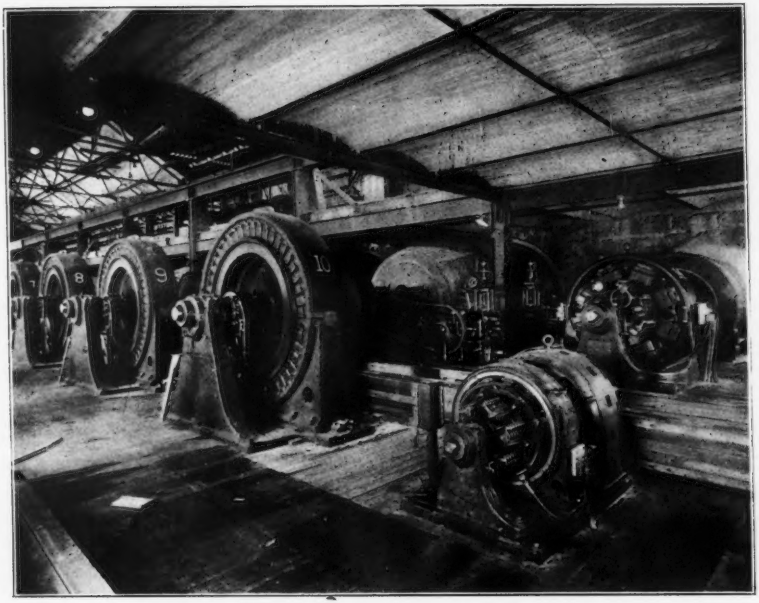


FIG. 1.—GENERATOR, WHEEL-CASE AND GOVERNOR.

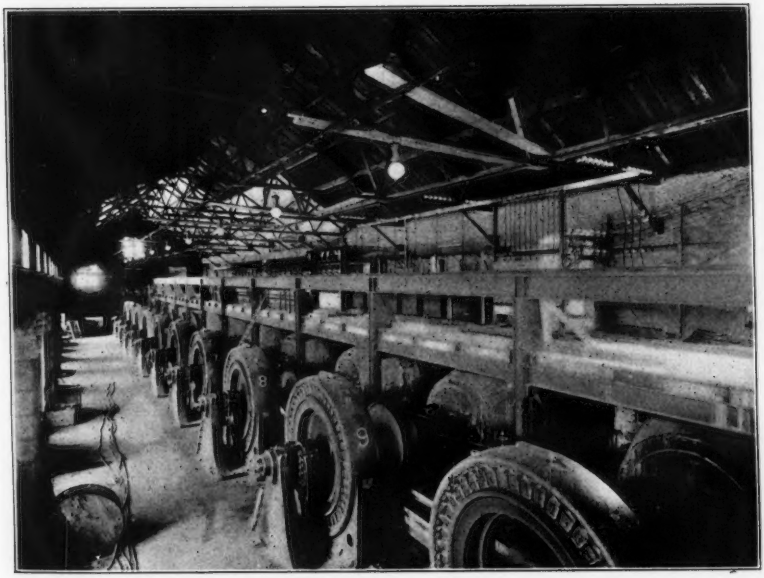


FIG. 2.—INTERIOR OF CANYON FERRY POWER-HOUSE.

FIG. 15.

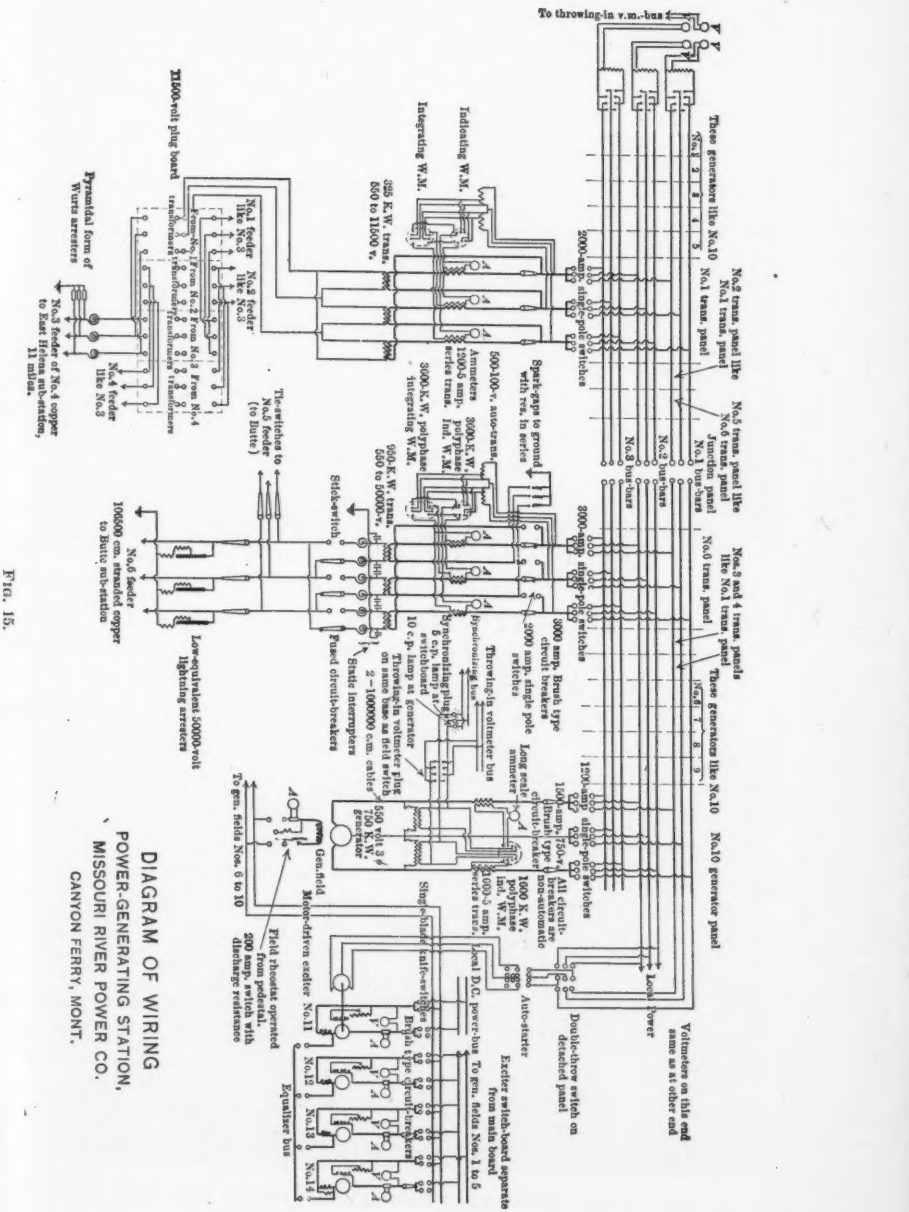


DIAGRAM OF WIRING
POWER-GENERATING STATION,
MISSOURI RIVER POWER CO.
CANYON FERRY, MONT.

FIG. 15.

The Transmission Lines.

There are three main pole-lines from the generating station: One carrying four power-circuits, each consisting of three No. 4, solid copper wires, and also a telephone circuit of two No. 10, copper wires. This line extends to the East Helena sub-station, where all the circuits pass through a four-panel plug-board, and lightning arresters of construction and arrangement similar to those on the same circuits at Canyon Ferry. Three circuits leave this sub-station, and, by means of the plug-board, any one or more of the four incoming circuits may be connected either with the sub-station lowering transformers, or with the three outgoing circuits, in any desired combination. After leaving the sub-station, the three circuits continue for about a mile on the same pole-line, and then branch—one circuit extending a distance of 5 miles to the Big Indian Mine, and the other extending 5 miles to the sub-station in Helena. The general design of the pole top, as arranged for the four 12 000-volt circuits leaving the generating station, is shown in Fig. 16.

The poles on the 12 000-volt lines are of Idaho cedar, the cross-arms of Oregon fir, the braces of angle iron, and the insulators of porcelain. The poles have from 9 to 12-in. tops, vary in length from 35 to 60 ft., when necessary to maintain the desired grade, are spaced at an average distance of 110 ft., and are set from 6 to 8 ft. in the ground. The main wires are not transposed, but the telephone wires are reversed in position at every third pole. The construction is heavy and rigid throughout, and has proved very satisfactory, as shown by the four years of unbroken service, almost without any expense for repairs.

The high voltage used on the Butte lines made necessary a special and somewhat novel construction. Each of the two pole-lines, from the Canyon Ferry generating plant to the Butte sub-station, carries three bare copper cables, arranged in a triangular position, 78 ins. apart. Each cable has an area of 106 000 circular mils, and is composed of seven strands. Fig. 17 shows the pole top, and Fig. 18 the insulator, sleeve and pin. Fig. 2, Plate IX, is a view of the pole-line taken about one mile from Canyon Ferry, and Fig. 2, Plate X, shows a 50 000-volt insulator and sleeve assembled on a pin.

The poles on the 50 000-volt lines are of Idaho cedar, the cross-arms of Oregon fir, the braces and pins of white oak, and the insu-

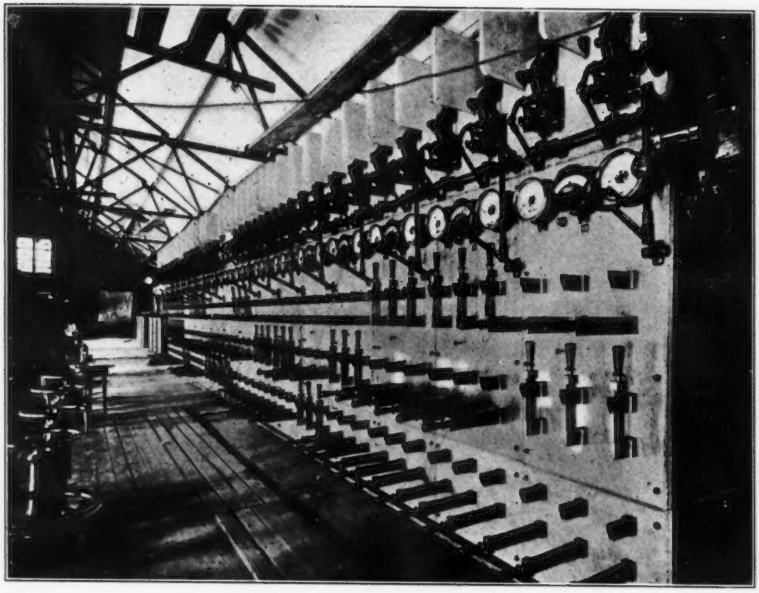


FIG. 1.—MAIN SWITCHBOARD, CANYON FERRY POWER-HOUSE.

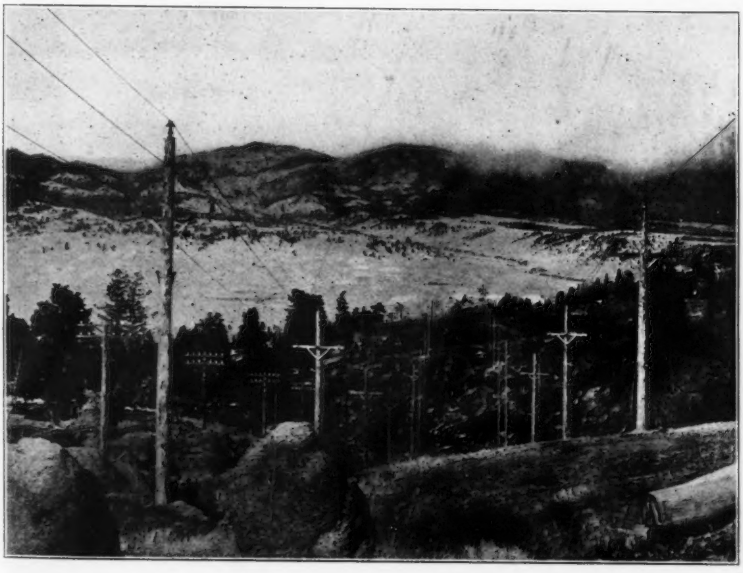
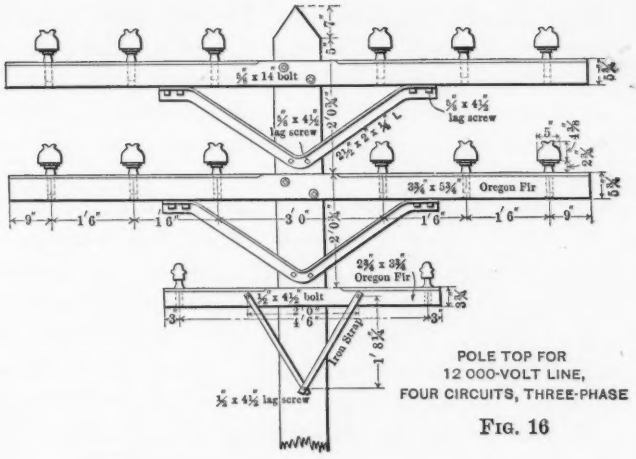
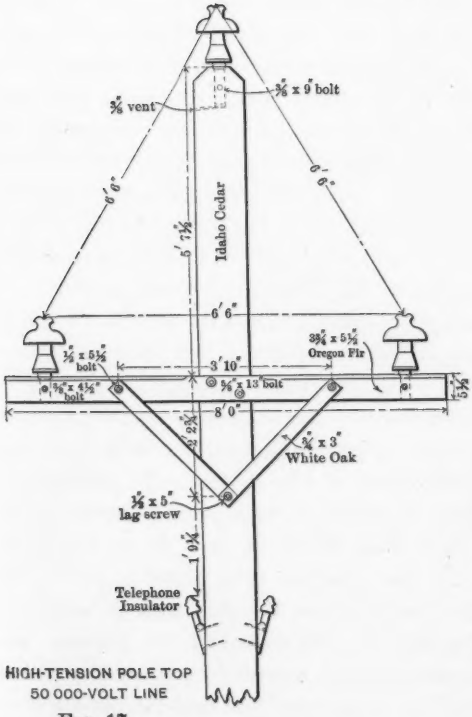


FIG. 2.—POLE-LINES NEAR CANYON FERRY.



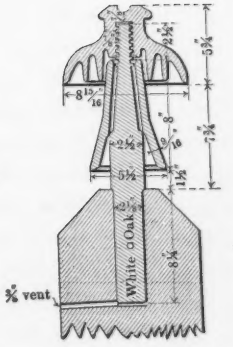
POLE TOP FOR
12 000-VOLT LINE,
FOUR CIRCUITS, THREE-PHASE

FIG. 16



HIGH-TENSION POLE TOP
50 000-VOLT LINE

FIG. 17



SECTION OF
50 000-VOLT
HIGH-TENSION INSULATOR,
SLEEVE, PIN, AND POLE TOP.

FIG. 18

lators and sleeves of glass. The cross-arms, braces and pins are bolted together, the construction being very rigid. The pins in the top of the poles are of larger size and of greater length than those in the cross-arms, on account of the greater strains there present. The pins were prepared especially by being first dried and then boiled in paraffin until every vestige of moisture was removed. Wood prepared in this way will stand very great electrical strains, and the pins were tested frequently to 60 000 volts, without sign of failing.

The insulation of the circuits depends on the insulators, sleeves and pins, combined; the cross-arms and poles are not considered to have any part. The glass sleeves are not connected in any way with the insulators, and merely rest on a shoulder of the pins, as shown in Fig. 18. The object of the sleeves is to prevent the surface of the pins from becoming wet in a driving rain, thus carrying the ground potential above the level of the cross-arms. This function they perform admirably, but if the pins were not especially treated, so as to possess high insulating qualities, the sleeves would be useless. With metal pins, or even ordinary wooden pins, which for such high potentials are practically conductors, the absolute insulation, the air path to ground, and the electro-static capacity, are affected to such an extent that the efficiency of the combination, as a line-insulating device, is reduced materially. Each of the main circuits is transposed five times, making two complete turns between the power-station and the Butte sub-station. The telephone circuit, as shown in Fig. 17, is on one pole-line, only, and is composed of two No. 10, copper wires on double-petticoat pony-glass insulators. This circuit is transposed every fifteen poles. The switching arrangements at Canyon Ferry and at Butte are such that the power circuits can be operated either singly or in multiple. The two Butte lines are parallel, and are 50 ft. apart, where the nature of the ground will permit. The poles are from 35 to 75 ft. in length, the tops being from 8 to 12 ins. in diameter, and the butts from 12 to 24 ins. in diameter, according to the length. They are set from 6 to 8 ft. in the ground, and the standard spacing is 110 ft., with a maximum spacing of 150 ft., when required by the nature of the ground. The angle turned on any one pole does not exceed 20°, except by special construction. A survey of the entire route was made, including levels at each pole; a ground profile was prepared, and the grade line for the


N
S
Helena
East Helena
12000-Volt Pole Line
Missouri
Canyon Ferry
Reservoir
Clancy
Jefferson
Boulder
Woodville
Burns
Substation
MAP OF POLE LINES
Scale of Miles
0 2 4 6 8 10
Contours at 500 ft. intervals

FIG. 19.

top of the poles drawn in. For the greater part of the distance, a right-of-way, 200 ft. in width, was obtained by purchase or condemnation, but, at a few points, and in passing through towns, it was necessary to follow the public highways, and in some of the narrow cañons, where there were already two railroads, it became necessary to follow in part the railroad rights-of-way. All the timber and brush within 50 ft. of the poles on either side was cut, and all high timber at a greater distance, which in falling could possibly injure the line. The contours on the map, Fig. 19, give an excellent idea of the nature of the country through which the lines are constructed. Starting from Canyon Ferry at an elevation of 3 650 ft. above mean sea level, the Butte lines pass over three distinct summits and reach a maximum elevation of 7 300 ft. Much of the country is very rough and wild, and the section between Boulder and Woodville is practically without inhabitants. Through this section it was necessary to build wagon roads, in order to handle the material, and much of the right-of-way was cleared through heavy timber. In certain sections the grades average 500 ft. to the mile, and the transportation of the material was one of the serious problems.

The Sub-Stations and Secondary Distribution.

There are three sub-stations connected with the system, and at a few other points power is delivered directly from the 12 000-volt circuits.

The East Helena sub-station is operated at 12 000 volts. It contains oil-insulated and air-cooled transformers, also lightning arresters and plug-boards similar to those installed at the power-station, and already described. Practically the entire capacity of this sub-station is utilized by the East Helena Smelter for a great variety of purposes, all the power at the works being derived from this source.

The Helena sub-station is also on the 12 000-volt circuits. It contains high-tension apparatus similar to that at East Helena and at the power-station. From this point is supplied all the incandescent and arc lighting, and the street railway and other electrical power for the City of Helena. As the apparatus here installed has already been described, and as this sub-station, as well as that at East Helena,

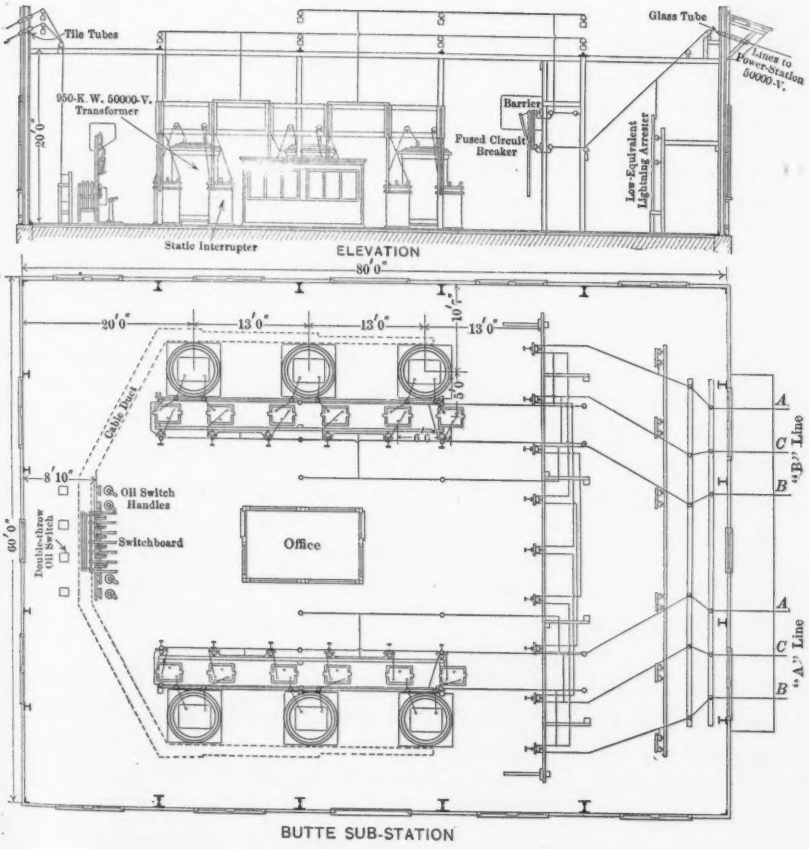

Tile Tubes
Glass Tube
Lines to Power-Station 50000-V.
950-K. W. 50000-V. Transformer
20′0″
Barrier
Fused Circuit Breaker
Low-Equivalent Lightning Arrester
Static Interrupter
ELEVATION
80′0″
20′0″
13′0″
13′0″
13′0″
10′0″
Cable Duct
8′10″
Oil Switch Handles
Switchboard
Double-throw Oil Switch
Office
60′0″
A
C
B
"B" Line
A
C
B
"A" Line
BUTTE SUB-STATION

FIG. 20.

represents only standard practice, no further detailed description is attempted.

The largest of the sub-stations is at Butte, having a transformer capacity of about 8 000 H.-P. The building is of steel and iron, with a brick floor and concrete foundations. The roof is lined with asbestos paper, held in position by wire netting. Fig. 20 is a plan of the building, showing the location of the principal apparatus. Fig. 1, Plate XI, is an exterior view of the transformer building, showing the method of entering the 50 000-volt lines. Fig. 2, Plate XI, is an interior view, showing the transformers, static interrupters, high-tension switches and wiring. Fig. 21 is a diagram of the wiring and connections of the apparatus. The 50 000-volt wiring is supported on glass line-insulators, and is of No. 4, solid copper, rubber-insulated wire, the same as that used in the generating station. The 2 200-volt secondary wiring from the transformers to the switchboard is of 800 000-circular mil cable, rubber-insulated, lead-covered, and laid in conduits under the floor. The 50 000-volt lightning arresters are duplicates of those in the generating stations, and are connected with each conductor immediately upon entering the building. After passing the lightning arresters, the main circuits pass through high-tension, fused circuit-breakers, then divide into a delta connection, inside of which is a pair of high-tension, fused circuit-breakers for each transformer, and also the static interrupters. Between the high-tension, line circuit-breakers and the branch of the delta connection, there are tapped, from each leg of the circuits, connections, through high-tension circuit-breakers, arranged so that the lines may be connected in multiple. All these connections are shown in the diagram.

There are six lowering transformers, of 950 kilowatts each, which are exact duplicates of those installed in the generating station, except that the coils of the low-tension side are connected in series, so as to give the electrical pressure of 2 200 volts instead of 550 volts. The six transformers are arranged in two groups, and on the 2 200-volt side are placed knife-switches and circuit-breakers, connected in the single-phase circuits inside of the delta connections. The three-phase connections are made at the main transformer panels of the 2 200-volt switchboard. There are two transformer panels, one for each group of transformers, and four main distributing panels. On each transformer panel is mounted a three-pole circuit-breaker, three ammeters,

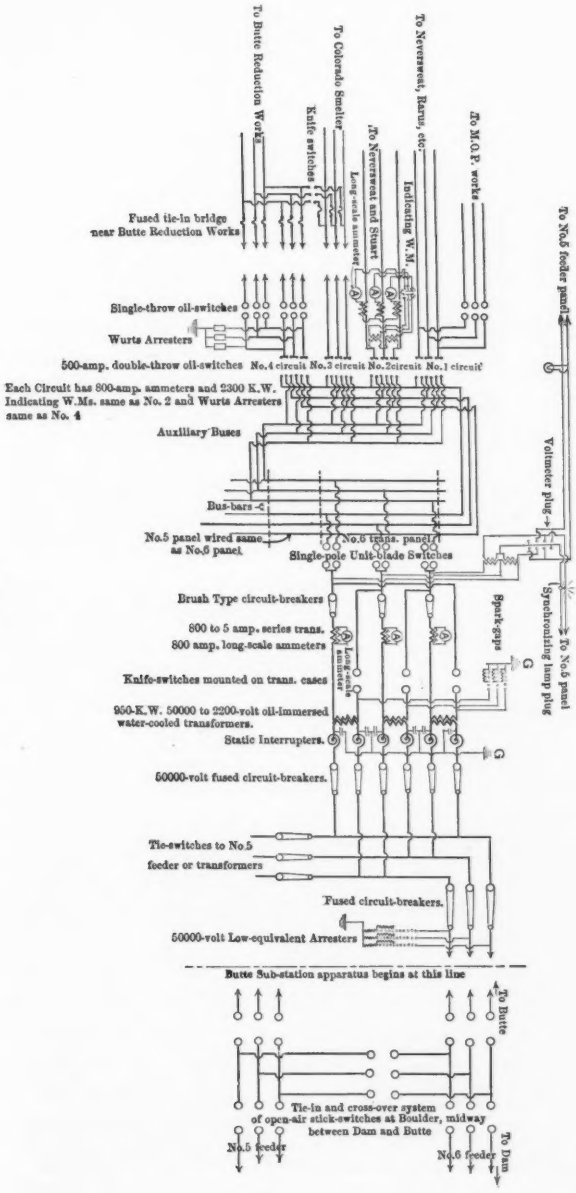


FIG. 21.

DIAGRAM OF WIRING,
BUTTE SUB STATION
MISSOURI RIVER POWER CO.

and six single-throw knife-switches. On each feeder panel is placed a polyphase wattmeter and three ammeters. In front of each feeder panel is a vertical switch-stand supporting an operating handle, controlling a three-pole, double-throw oil-switch, located back of the board. There are two sets of 2 200-volt bus-bars, and the knife-switches on the transformer panels are arranged so that either one or both sets of transformers may be connected with either set of bus-bars; or both sets of bus-bars may be connected with one set of transformers. Also, a single transformer may be cut out at any time, and the two remaining transformers supply current to the bus-bars. By means of the oil-switches referred to, the load can be transferred to either side of the bus-bars, or cut off entirely, without opening the transformer connections. After leaving the main-feeder oil-switches, the current again divides and passes through three-pole automatic oil-switches, one for each outgoing circuit. There are six of such circuits at present, and other circuits, with oil-switches, will be added as required.

The lightning protection on the 2 200-volt low-tension side of the transformers is provided for by the following arrangement: A lightning arrester having four $\frac{1}{16}$-in. gaps in series with a resistance, is connected, through a 5-ampere enclosed fuse, directly with one 2 200-volt terminal of each transformer. At the switchboard a similar lightning arrester is connected with each of the six bus-bars. On the feeder-circuits, just before leaving the building, a lightning arrester is connected with each leg, consisting of twelve $\frac{1}{32}$-in. gaps in series to ground, without fuse, but having a fuse and resistance shunted around six of the gaps.

There are three pole-lines carrying the six feeders from the substation to the points where the power is distributed; one line, carrying three feeders, extends a distance of $2\frac{1}{2}$ miles to the Butte Reduction Works, and, with two circuits, continues $\frac{1}{2}$ mile further to the Colorado Smelter. The second line, carrying two circuits, extends $1\frac{1}{2}$ miles over the Butte Hill, to the Anaconda Mines, where large blowing engines are operated, and whence radiate a number of lighter pole-lines, carrying circuits distributing power to most of the large mines in Butte. The third line extends about 2 000 ft. to the smelter and other properties of the Montana Ore Purchasing Company.

There are connected to the Butte circuits an unusual number of

FIG. 2.—INSULATOR, SLEEVE AND PIN FOR 50 000 VOLTS, ASSEMBLED.

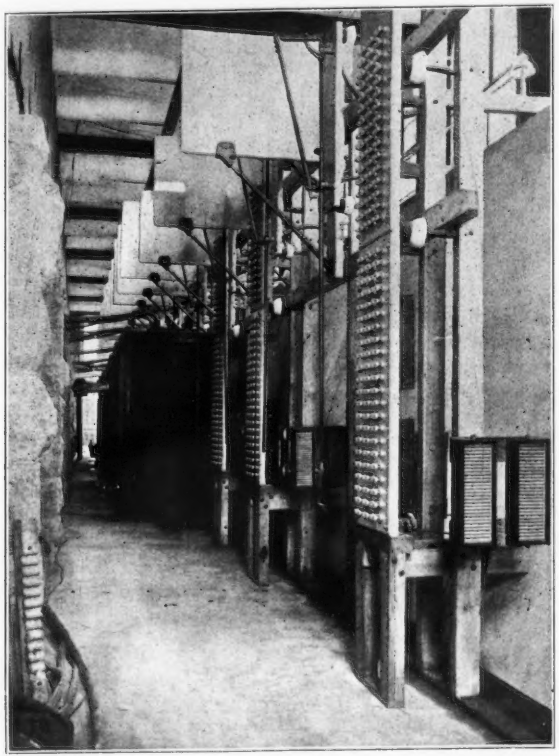


FIG. 1.—END VIEW OF 50 000-VOLT TRANSFORMER ROOM.



FIG. 2.—INSULATOR, SLEEVE AND PIN FOR 50 000 VOLTS, ASSEMBLED.

large motors, of 200, 300, 600 and 800-H.-P. sizes, mostly of the induction type. Fig. 1, Plate XII, shows one of three induction motors of 300 H.-P. operating at the Colorado Smelter. Fig. 2, Plate XII, shows an 800-H.-P. induction motor of 175 revolutions per minute, used in driving an air compressor at the Anaconda Mines. This last-mentioned motor is believed to be the largest induction motor of such slow speed ever installed.

The Operation of the Plant.

In the operation of a transmission plant and system like that of the Missouri River Power Company, starting with a given plant and water supply, the desired result is the delivery, at distant points, of the greatest amount of electrical energy, in the most salable and satisfactory form, at the lowest possible cost.

For the generation of the power, a certain river flowage is available, varying with the seasons and the years. There is also available a large pond or reservoir which may be drawn upon to supply water in excess of the river flowage for short periods of time. The first important consideration is the nature of the load, whether variable or steady, and whether extending over a few hours or the entire day. The most convenient way of expressing this condition is by reference to the load factor, *i. e.*, the ratio of the average to the maximum load, expressed as a percentage, for the period of time over which the factor is determined. Integrating wattmeters furnish a ready means for determining with accuracy the average electrical power, and the maximum power can always be measured by various indicating or recording instruments. The load factors of several circuits supplying power for a variety of industrial purposes will usually differ widely, and the best result, as far as station loading is concerned, will be obtained by uniting all on one set of bus-bars, and operating the entire station as a unit. Sometimes this is impossible on account of different electrical pressures being demanded, or on account of certain circuits requiring greater refinement in regulation than others. The conditions at Canyon Ferry have been adjusted so that it is possible to operate all circuits together, so that the generating machinery is working at one load factor, or about 90% for the 24 hours; the load factors of the several circuits varying meanwhile among themselves from 95% on some to 10% on others. It is evident that the higher the load factor,

the smaller the machinery capacity required in service to carry a given average load; and it also follows, in general, that the efficiency is greater because the machinery can be operated more nearly at its full load.

The load factor also has an important bearing upon the speed regulation of the water-wheels, and upon the electrical regulation of the system. Commercial considerations frequently require the acceptance from a customer of a power load of load factor, but it is the best practice to regulate the design so that such loads can be combined with others, resulting in an average condition more favorable to economical operation. It is the practice of the Missouri River Power Company to operate the entire station as a unit, connected in multiple, but the design is such that circuits can be operated separately under special conditions, or in emergencies of any kind. The station load factor being determined, the amount of average power which can be generated will depend upon the flow of the river, provided there is a pond or reservoir affording water storage sufficient to permit the carrying of the peak loads, without seriously affecting the head. This is a most important matter, as it permits the plant to carry an average load fully up to the flowage of the river, while, without such a reservoir, the power generated could not exceed the maximum at the station, which would be materially less than the average. At Canyon Ferry the pond is ample for this purpose.

Next in importance to the form and amount of loading on the station is the question of speed regulation. For many years close speed regulation was thought impossible for water-wheels driving machinery subject to suddenly varying loads; but the difficulties have been overcome, and it has been found that very satisfactory results can be obtained by correct designing, and the use of proper governors to actuate the water-wheel gates. The first consideration is to have such hydraulic design that the water can pass freely to the wheels, and to avoid those arrangements which require a considerable change in the velocity of the water, with varying gate on the wheels; such, for example, as long penstocks having little hydraulic grade. If the design in this particular is bad the regulation will suffer, regardless of the excellence of the governor, as a time element will be introduced in which the water column will be accelerated or retarded, and during which the water-wheels cannot fully respond to the gate opening, on

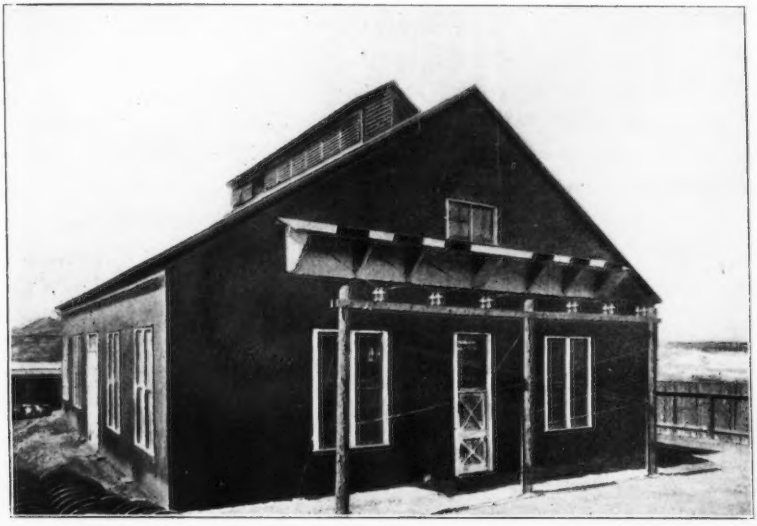


FIG. 1.—SUB-STATION AT BUTTE.

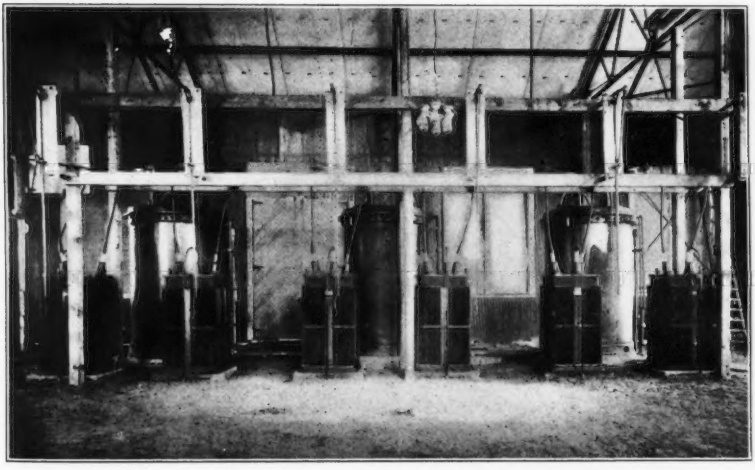


FIG. 2.—INTERIOR OF SUB-STATION AT BUTTE.

account of the varying effective head. One of the principal reasons leading to the removal of the old penstocks and the construction of the open canal at Canyon Ferry was to obtain better design in this particular, resulting in better speed regulation for the plant. The nearer the design approaches to an absolutely open setting, with the head entirely above the wheels, the better the regulation. From an inspection of the drawings it will be seen that the water passages from the canal to the wheels are very direct, and that the design approaches closely to the most desirable conditions. Next in importance, after proper hydraulic design, is a good governor, having ample power, and proper arrangements for relaying and returning the speed to normal at all points of the gates. It is also essential that the governors have a distinct speed characteristic, in order that the various wheels driving generators connected electrically in multiple may divide the load properly at all points of gate. If the governors do not have such a speed characteristic, the conditions will be unstable, and the wheels will shift the load between themselves, some taking more than others. The governor used in this plant is well known, and possesses the requirements mentioned. Besides a good governor, it is necessary to have a water-wheel with gates designed for easy control by the governor mechanism. Builders of water-wheels have given this subject considerable study, and great improvements in design have been made in this particular. The essential requirements are that the gates move easily at all points, and possess little inertia. The cylinder and wicket types of gate alone seem to meet these requirements for turbine wheels without seriously sacrificing efficiency. The new wheels at Canyon Ferry have cylinder gates, and the speed regulation does not exceed 3% under severe changes of load, and 2% under ordinary working conditions.

Of the operating electrical features, that of most general interest is the high voltage on the Butte transmission circuits. The electrical pressure is maintained regularly at 50 000 volts and more. This is a pressure higher than that used in regular commercial service elsewhere at the present time, within the knowledge of the writer. For many months a regular commercial service has been maintained at this pressure, and the results have been very satisfactory. Lightning, wind, rain and snow have not interfered with the regularity of the service. The electrical losses due to the pressure are trifling in

amount and far less than the gain in other respects from the same cause. The behavior of these circuits does not differ greatly from similar circuits at lower voltages, and there are no luminous effects, or discharges, on the lines, under normal working conditions. A very satisfactory telephone service is maintained on one of the high-tension pole-lines.

The two transmission lines to Butte are generally worked in multiple, but each line has ample capacity for carrying the entire load, when necessary. In the operation of the plant it is customary to energize the lines separately from the station, and to synchronize and tie the lines together at the Butte sub-station. The overload switches and other special devices, already described, provide ready means for disconnecting any line or feeder, and any single unit or group of units of apparatus, either at the power-station or at the sub-station, can be put into service or instantly removed therefrom without affecting the service, or without the knowledge of the customers that anything has taken place.

The regulation of the electrical pressure is one of the most important factors in the successful operation of a transmission system. The maintenance of practically constant speed is, of course, a requisite. The generators should have good inherent electrical regulation, not only for changing load, but more especially for varying power factor. The electrical regulation of the transformers is of importance, but more especially is that of the transmission lines and feeders. The inductance, capacity and resistance of the transmission circuits can be controlled in design to a certain extent, and, if the nature and amount of loading are known in advance, the line regulation can be predetermined with accuracy. The nature of the load, especially as to its power factor, has a most essential bearing on the regulation. By uniting the various loads and working the entire system as a unit, there is obtained, under ordinary conditions at Canyon Ferry, a station power factor of about 90 per cent. The regulation at the Butte sub-station is within 5% of normal, under regular service conditions. The problems of electrical design and operation involved in this subject are complex, and are not within the scope of this paper, hence are not here treated mathematically or in detail.

At the generating station, the usual operations of starting, stopping, switching, paralleling and synchronizing are those common to all large power plants, and do not merit special description.

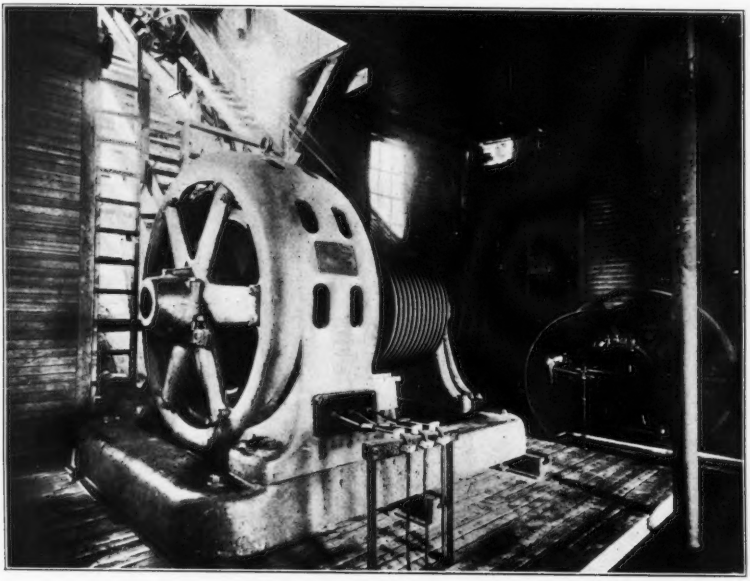


FIG. 1.—A 300 H.-P. INDUCTION MOTOR IN COLORADO SMELTER.

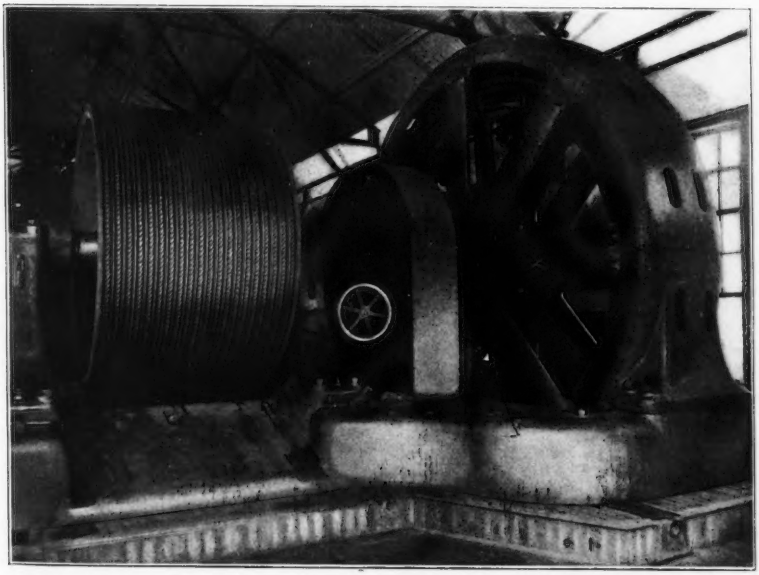


FIG. 2.—AN 800 H.-P. INDUCTION MOTOR AT ANACONDA MINE.

The writer desires to acknowledge the valuable services rendered, both in designing and construction, by his able assistants: James C. McKitrick, C. E., in charge of the general construction at Canyon Ferry; A. C. Pratt, E. E., in charge of the power-station machinery and electrical construction; Wm. L. Miller, E. E., in charge of the sub-station and all construction in the City of Butte; and Mr. E. E. Davis, in charge of all transmission-line construction.

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PAPERS AND DISCUSSIONS.

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THE SANITARY DISPOSAL OF MUNICIPAL REFUSE.

An Informal Discussion.*

By Messrs. Rudolph Hering, H. de B. Parsons, W. F. Morse, George A. Soper, Theodore Horton and Elmer W. Firth.

Presented at the Meetings of December 17th, 1902, and January 7th, 1903.

Mr. Hering. Rudolph Hering, M. Am. Soc. C. E.—The subject herewith presented for discussion does not include the disposal of sewage. This has already received much attention and fairly satisfactory solutions. It embodies the treatment of the miscellaneous solid materials which are not removed by water carriage in underground channels, but require special cartage, and the best disposition of which is not yet generally recognized. The subject, in fact, is still under development, and, so it seems to the speaker, has now reached a stage where it requires the assistance of the civil engineer to bring it to a satisfactory state of practice.

For convenience of discussion, perhaps also of treatment, the materials included may be divided into four classes:

I.—Ashes;
II.—Street sweepings;
III.—Dry rubbish;
IV.—Kitchen garbage, swill or slop.

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. xxv, p. 71.)

Communications on this subject received prior to February 28th, 1903, will be published subsequently.

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The problem before the engineer, therefore, is to effect a sanitary collection and disposal of these four classes of refuse at the least cost. For this purpose he must ascertain and carefully consider:

A.—The objectionable qualities of each class of refuse, viewed from a sanitary standpoint; which means the destruction of disease germs, the avoiding of a nuisance and the seeking of comfort and decency in the handling of this matter.

B.—The cost of collection—from the place of origin to that of final disposal—and the cost of final disposal, modified by any credit that may be due to a salable value of any part or parts of the refuse.

A.—Sanitary Collection and Disposal.

I.—Ashes.—The objectionable feature in the collection and disposal of ashes is the dust. When placed on the sidewalk, when carted through the streets, or when dumped while the wind is brisk, the arising of dust is a nuisance.

The evident and simple remedy against dust, when collecting ashes, is the use of covered receptacles and covered carts, and, when disposing of them, is a careful and slow dumping, or, on special occasions, perhaps also a prior wetting.

The filling in of low ground is the usual way of disposing of this material permanently. Occasionally, it has been utilized as an ingredient for mortar or for road-making.

II.—Street Sweepings.—Street sweepings consist of horse droppings, accumulations of general city dust and dirt not separately removed, and earthy material worked to the surface of pervious pavements or brought by wheels from country roads.

The composition of sweepings, therefore, varies with the quantity and quality of traffic, the kind of pavement, and the distance from unpaved roads. The sweepings may contain a large or a small proportion of organic matter, some of which may break down rapidly and some slowly. The fineness of this material is its chief objection, as the wind readily takes it up and blows it about, to the injury of man, of beast, and of certain kinds of property. Germs of the most prevalent city disease, tuberculosis, may be abundant in the street dust, and the troubles of the continual warfare against this dust, when settling in the rooms of our houses, are known to all.

Sprinkling and sweeping at frequent intervals are the recognized, though often inefficiently executed, remedy against the dust nuisance within the city, and covered carts are also here required for the proper removal of the material.

Its final disposal can be effected in either of several ways. When mixed with fuel, and especially when containing but little inorganic matter, it can be burned, which destroys effectually the organic matter,

Mr. Hering. including disease germs, contained therein; or, it can be dumped for the filling of low land, which can be quite satisfactory in many cases. When dumped, the upper surface of the fill alone remains exposed to the wind, and this only temporarily until vegetation protects it. When street sweepings contain a large proportion of organic ingredients, as horse manure, they are utilized as a fertilizing agent, with more or less success, and with the concomitant elimination of their objectionable qualities.

III.—Dry Rubbish.—The dry rubbish of a community consists of that aggregation of material which is not classed especially under the other headings. It consists chiefly of wood, paper, straw, leaves, rags, leather, stoneware, glass, metals, and sweepings from buildings. Its most objectionable qualities are dust and lurking disease germs. It is not easily decomposed, and its odor is but slightly offensive. Its value consists partly in the material that may be picked out, assorted and sold, such as metals, glass, and discarded articles of manufacture, and partly in the fuel constituents which it retains after such picking.

Its collection should be made in covered carts, to prevent odors, dust, and other nuisances. The frequency of collection is not an important question, due to the character of the material.

Its final disposition, after it has been picked over, is usually either as filling of land, by dumping, or as fuel, by cremation.

Filling up low land with this rubbish was an early practice, and still persists in many places. Where land is available, where such material will not cause future trouble, and where it cannot be burned economically, this practice cannot be seriously objectionable. Where the rubbish can be properly burned, such practice would generally be preferred by the medical profession.

IV.—Kitchen Garbage, otherwise called Swill or Slop.—Garbage proper is the refuse chiefly from kitchens, markets and slaughter houses, and consists almost wholly of rejected animal or vegetable matter in solid and liquid form. A large proportion, therefore, readily breaks down, and, on becoming putrescible, spreads offensive odors about.

It is the most important part of city refuse, both because it is likely to create the greatest nuisance, and because it has the greatest inherent commercial value. It has been the subject of more discussion, its treatment has been more varied, and a satisfactory solution of the problem of disposal is less generally acknowledged, than in the case of the other classes of refuse.

Regarding the best manner of collecting this material, there is but little question. It is generally conceded that it should be placed in water-tight and covered receptacles, and collected in water-tight and covered carts or wagons. It is also conceded that the collection should be frequent. The frequency, however, varies often with the

density of population. Yet this density affects only the quantity of the material, not its liability to putrefy, which is controlled wholly by its composition, the length of time it is exposed, and by the temperature. That the latter fact is beginning to be recognized in some cities is evidenced by ordering more frequent collection in summer than in winter. The necessary frequency should also vary with the manner of disposal. If, for instance, garbage is fed to swine, then, for sanitary results, a daily collection is peremptory throughout the year, except only in very cold weather. Mr. Hering.

In northern climates, where winters are cold and long, the receptacles, for obvious reasons, are better made of wood than of metal, while in warm climates the reverse is true, which conclusion is already recognized occasionally. Where garbage is likely to freeze while waiting for a collection, a conical-shaped receptacle is the only proper form.

The final disposition of this material is now being effected in the following ways:

1.—Feeding to swine,
2.—Dumping as filling,
3.—Dumping into large volumes of water,
4.—Ploughing into soil,
5.—Extracting the grease,
6.—Cremating the organic matter.

Feeding to Swine.—This was one of the first methods of disposal ever used, and it is still practiced extensively. In New England it is the prevailing method in small and medium-sized communities. If kept free from other refuse, and from such as would injure its food quality, if collected and properly delivered daily, there seems to be no serious objection to this method, either from a hygienic or commercial standpoint. It has an advantage over all other methods in yielding a revenue from its sale, which is sometimes greater than that obtained through any other method of disposal. Its application, however, must be confined to conditions under which the sanitary quality of the food, respecting disease germs and odors, can be safely guarded and maintained, and which excludes it from adoption in large cities, except in the case of hotels and eating-houses, where a private collection can be secured.

Dumping as Filling.—This is practiced in places where feeding is found objectionable. When not mixed with other refuse, dumping is objectionable on account of the subsequent putrefaction, in case of a large accumulation of the garbage. When mixed with other refuse, the merits of dumping depend on the proportions of the ingredients of the mixture, and on the character of the locality where dumped. Under some conditions a nuisance would, and under others would not, result.

Mr. Hering.

Dumping into Large Volumes of Water.—This method can, or cannot, be advised according to the special conditions of the case. Like the disposal of sewage by dilution, a safe disposal of garbage can be effected by dispersion, if the quantity of water is sufficient, if the current or winds prevent a drift ashore, and if the sinking material does not accumulate so as to reduce the necessary channel depth for navigation, or produce foulness by deposit on shallow areas. Opportunities for a satisfactory disposal in this manner will be rare.

Ploughing into Soil.—This has been practiced with varying success. If freed from metals and large entangling objects, and if mixed with barren sandy soils or acid soils, garbage being somewhat alkaline, good results have been obtained for the raising of crops under careful management. This process is at present considered favorably in several cities of Europe, because it can dispose of disease germs and odors satisfactorily, and because its gradual nitrification has produced a fertile soil where sterility had previously prevailed.

Extracting the Grease.—The extraction of grease from garbage is an American industry which has been promoted in a number of our cities. The process in its general form consists briefly in separating the material into two parts, each having a salable value, namely, oil, or fat, and a dry, stable, fibrous material of vegetable and animal origin, called tankage, and used as a filler or diluter for certain fertilizers. The separation is brought about by simple boiling and subsequent pressing out of the oil and water, which are in turn separated by gravity. Or, it is accomplished by an admixture with naphtha, which dissolves the oil, and later, after it is separated from the tankage and cooled, enables it to be readily extracted. The water separated from the oil is an offensive liquid, and the gases and fumes generated at the works are offensive vapors. Both require a careful and thorough treatment.

The objections to this reduction method of garbage disposal, which is still practiced in Boston, New York, Buffalo, Philadelphia, Washington, St. Louis, Cincinnati, etc., although abandoned in some cities, is due to the offensive odors occasionally, if not continually, arising from the same. The process requires the rejection at the works of tin cans and other foul material which interferes with the economical process of securing the oil. For such rejected material a different treatment and disposal is necessary. While, from an engineering point of view, it is practicable to construct and operate these reduction works so that odors will not prevail, the means for doing so are also expensive. As they are operated invariably as a business undertaking for profit, the conflicting interests naturally involve the constant danger of a possible nuisance. The practical result has been that, for the sake of sanitary security, such works are now placed as far from inhabited territory as practicable, with the disadvantage that the distance for transportation has become correspondingly greater.

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The advantages of this method lie chiefly in the commercial value of the oil and in the destruction of disease germs and putrescible matter by heat. There is little value in the tankage, which is occasionally used as a fuel or even wasted on dumps.

After all the operations of a reduction process have been conducted without offense, the financial aspects will decide the permanent merits and value of this method of disposal.

Cremating the Organic Matter.—This is the favorite and exclusive method of garbage disposal in England, where it has been used for fifty years; and it is also the favorite one of the medical profession. In the eyes of the sanitarian the complete destruction by fire of all matter that may become offensive, and at the same time of all disease germs that may lurk in the sweepings of the house and in the rejected food materials, is an ideal process.

In practice, however, the results have not always been ideal. In our country odors from such works have been complained of in many instances, and a number of crematories have been abandoned as nuisances. In England, however, such has not been the case. Furnace extensions are built every year. Complaints are rare. In Hamburg, Germany, where is the largest single garbage crematory in existence, this is giving no offense, although adjoining a built-up section.

An examination into the reasons for the different results achieved by cremation in Europe and America shows that the elements making up the problem are not the same.

1.—The material as it is burned in Europe has not the same composition as that which here has failed to burn properly. European success was achieved with refuse generally consisting of a mixture of garbage with ashes and dry combustible rubbish. The chief failures in America are recorded where garbage alone was cremated, without the admixture of other combustible dry refuse, and even after the addition of furnace coal. An examination into the combustibility of European and American combined refuse does not show a great difference. The few analyses we have show that cremation under proper precautions and suitable conditions should be as practicable here as in England, and recent furnaces built here demonstrate this fact.

2.—The essentials in the construction of the successful English furnaces differ from those of the furnaces peculiar to our country, where they have not been satisfactory. The English furnaces are built with sloping grates of small area, while the American furnaces generally have horizontal grates of large area. It is hardly necessary here to point out that in this element lies a main defect of our plants. A sloping grate admits of an almost automatic continuous process of gradual drying, then heating, and finally burning; the fresh material being added at the upper end and the hottest fire being near the lower end. A horizontal grate, on the other hand, to secure proper combus-

Mr. Hering. tion, depends almost wholly upon stoking, which causes the burning to be irregular, due to the sudden dropping of cold and perhaps wet material upon that which is already almost completely burned. In Europe we also find an extensive use of large dust chambers to prevent the escape of this fine material, of which we so often hear complaint. We find also a more frequent and effective placing of dampers to control the draughts, and thus prevent the escape of unburned, and therefore odorous, solid particles and gases. Finally, more attention is directed there than here to the evolution of the greatest possible heat for the incidental production of steam.

3.—The expert garbage fireman, who is considered essential to success in England, is generally supplanted here by a man whose only qualification for the position may be that he can shovel coal or pull out clinkers, but generally has not the remotest knowledge or even conception of the difficulties in burning, on a large scale, both continuously and completely, the most heterogeneous mixture of all forms of solid matter to be gathered from a modern community. The advantage of a trained expert in firing city refuse was well shown by the fact that until Hamburg imported English firemen to train the German firemen in the mere operation of their own plant, satisfactory results could not be obtained.

4.—In Europe, the municipalities, under the guidance of experienced engineer officers, generally undertake the cremation by their own long-trained employees, while here usually either the health boards or council committees select not only the design, but indicate the method of operation, appoint inexperienced employees, or enter into a contract for immediate profit rather than for permanent efficiency. The difficulties underlying the problem of city refuse disposal, which is almost wholly one of engineering, have been solved satisfactorily where competent engineers have been employed for the purpose. It is hardly to be expected that, without professional skill and training, desirable results can be reached in this, any more than in any other, branch of engineering.

It will therefore rest finally upon our profession to solve this urgent question in our country, by not only making the necessary preliminary investigations to determine the most economical means of disposal, to indicate the methods, and to design the works that will accomplish this in a sanitary and inoffensive way; but, also, by indicating the details of operation most suitable for the particular kinds of material delivered.

B.—Cost of Collection and Disposal.

In discussing this subject, in full view of what has been said regarding the sanitary demands, we are now able to add that the latter demands can be satisfied by the engineer in any and all of their aspects if the necessary price is paid. He is therefore obliged to estimate,

here, as in his other problems, the cost of each method, developed to a point of satisfactory efficiency. The least expensive of the several possible methods will then become the preferable one. As the question of cost embodies the collection, from the point of origin to the point of disposal, the estimate must embody the expense required between these two points; for one process may require a much longer haul than another; then, to be economical, the disposal in the first case must cost proportionately less than in the second. Mr. Hering

Theoretically, it would be proper, in a given case, first to estimate the cost of properly collecting and disposing of each class of refuse, separately, in accordance with the several practicable ways indicated. Then it might appear that perhaps some two or three or all four classes of refuse could be treated economically by the same process. In this event a second estimate of cost would be appropriately made for a system of combining the collection and disposal of two or more such classes of refuse, and thereby the expediency of a system of separation or combination, in part or as a whole, would be ascertained. In practice, this procedure sometimes might be very simple.

In making such estimates of cost it is necessary to take account of both debit and credit sides of the financial aspect.

The collection is a debit in every case, its amount depending upon the distance the refuse is hauled. When garbage is fed to swine, the collection should be more frequent than in other cases, and a further debit would be proper on that account.

The final disposal has both debit and credit sides to be investigated. In the case of kitchen garbage and dry rubbish a substantial debit is required in establishing preventive and precautionary measures against the arising of offensive odors, of dust or other nuisances, in whatever process of disposal may be considered. On the other hand, the credits must be determined, as the case may be, and, if found to exist, they may be given to the several classes of refuse as follows:

Ashes.—By filling land, utilization for road-making, or as an ingredient of mortar, or otherwise.

Street Sweepings.—By making land or by utilization as manure, or otherwise.

Dry Rubbish.—By utilizing whatever value exists in the pickings, and in the remainder as fuel for power purposes.

Kitchen Garbage.—By utilizing its value either as food for swine, as grease and fertilizer, or as a heat producer for power development.

If the subject under discussion is treated substantially as above outlined, the speaker believes: First, that, through the co-operation of the engineering profession, it will gradually cease to be a vexed question among our legislators; secondly, that the sanitary demands, in preventing nuisances and dangers to health, will be satisfied; thirdly,

Mr. Hering. that the economical advantages inherent to the several processes will be secured; and fourthly, that the result will be an efficient process operated at the lowest cost.

Mr. Parsons. H. DE B. PARSONS, M. Am. Soc. C. E.—The primary collection of the refuse of a municipality is made by carts, which convey the waste material to points for final disposition. This primary collection presents no special difficulties. It is a matter of carefully working out the details to suit best the existing conditions.

The problem that is serious and difficult to solve is that of the final disposition of this refuse—a problem which is closely allied to the health of the community. The direct benefits derived by a suitable system for sanitary disposal are augmented indirectly by an increase in the health of the community.

No matter how the question is approached, the practical considerations of first cost and expense of operation and maintenance will be found paramount. On this account, as well as the short tenure of office of our city authorities, systems have come into use which are neither the most sanitary nor most economical for final disposition. Contracts have been let for such short periods that contractors have refrained from erecting suitable plants, and systems have been evolved which only earn for the cities a portion of the direct returns that might be obtained.

The refuse of a municipality consists of garbage, ashes, rubbish and street sweepings. In an average American city the divisions are proportioned approximately, as follows:

	By weight.	By volume.
Garbage	13 per cent.	18 per cent.
Ashes	80 "	57 "
Rubbish	7 "	25 "

The statistics gathered from one city are not applicable to another; and results predicated on information obtained from other places will not always be satisfactory. In order to make a final solution of the problem, it is necessary to study the conditions obtaining in the particular place under consideration. Garbage is combustible. It is extremely difficult, however, to burn pure garbage, and it has been found necessary to mix fuel with it in order to obtain complete combustion. The amount of fuel required varies from 8 to 20% of coal by weight, according to the character of the place and the constituent elements of the garbage. Ordinary kitchen garbage consists of approximately, by weight:

Animal and vegetable matter	20 per cent.
Grease	3 "
Water	70 "
Rubbish, cans, rags, etc	7 "

Mr. Parsons.

Ash collections are divisible into two kinds, steam ash and household ash. The steam ash, produced by manufacturing companies, comes to a city dump practically pure. It is clean and contains little unburned coal. The household ash, on the contrary, contains a large quantity of unburned coal. It has been estimated that, in a city like New York, the quantity of unburned coal in the ash carted to the dumps from private houses and apartment houses amounts to about 20%, and, in the speaker's experience, there is little question but that the proportion is correct. This coal, mixed with the ash, can be and is utilized as fuel to assist in the combustion of garbage. The ash collections make a good filling material, and can be disposed of for that purpose.

Rubbish collections are very combustible, as are also the street sweepings.

Final disposition of the refuse may be made, first, by dumping on waste lands, or at sea; secondly, by sending the garbage to reduction works, cremating the rubbish, and utilizing the ash collections for filling; and, thirdly, by cremating the garbage and rubbish, and utilizing the ash collections for filling.

The first method is neither sanitary nor satisfactory.

The second method is sanitary, but not wholly satisfactory. The reduction works can only handle garbage, and the system is considered uncertain in case of an epidemic, as the employees might refuse to work the plant. Such works can only afford to operate on a bonus paid by the city. The process consists of extracting the moisture by pressure, as being cheaper than evaporation, and of cooking the material by steam in large tanks or digesters. The products are grease and a residue sold as fertilizer. The plants are expensive to construct.

The third method is sanitary, and, in the speaker's judgment, the best; because it has been accomplished without creating a nuisance, because it is the most sanitary, and because it can be made to produce the greatest revenue. To be successful the combustion must take place at a high temperature, say between 1 500 and 2 000° Fahr. The household ash, the rubbish and the street sweepings will supply the fuel.

Cremation has been tried, in a number of places in America, with poor results, although very successfully practiced in Europe. The failure in American cities has been largely due to faulty design of the furnaces, lack of high temperature (a most essential feature), and want of means for properly caring for the garbage when first brought to the destructor. When garbage is allowed to collect in mass, it is most highly objectionable, and such collections have caused, in some instances, the failure of what otherwise might have been a successful plant. The heat generated can be used for various purposes and be made income-earning.

Mr. Parsons.

CONDITIONS IN THE CITY OF NEW YORK.

Area of Greater New York	320	sq. miles.
" " Borough of Manhattan	39	" "
Paved Streets, Greater New York	1 000	" "
" " London	1 818	" "
" " Paris	604	" "
" " Berlin	500	" "

The amount of refuse collected yearly in the Boroughs of Manhattan, Bronx and Brooklyn is about 2 800 000 tons. The collections, in pounds per capita per week day, are about as follows:

Garbage	0.4 lbs.
Ashes	2.5 "
Rubbish	0.3 "
Street sweepings	0.7 "
Total per capita per week day	3.9 "

Comparing this record with other cities, of which the records are believed to be fairly accurate, the following comparison is made:

New York	3.9 lbs. per capita per day.
London	1.6 " " "
Berlin	0.9 " " "

Results varying so widely show the difficulty in predicting what can be done with a municipal refuse, unless one knows in advance the character of the waste.

The rubbish collections in New York City weigh, on the average, about 250 lbs. per cubic yard. In Boston they weigh about 202 lbs. per cubic yard.

These rubbish collections have been divided as follows:

	By weight.	By volume.
Combustible material	60 per cent.	37 per cent.
Incombustible material (valueless).	5 " "	3 " "
Marketable material	35 " "	60 " "

The rubbish is picked over at the dumps by a trimming contractor, who pays the city for the privilege. The value of this marketable material to the city is about $3.20 per ton. The Commissioner of Street Cleaning has stated that this figure is too low; probably it should be increased 50 per cent. It is figured as follows: The average rubbish collections are 300 tons per day, or 1 800 tons per week, of which the marketable or salable material is 35%, say 600 tons. For this the contractor pays the city approximately $1 920, or at the rate of $3.20 per ton.

The present Commissioner of the Department of Street Cleaning had an incinerating plant* constructed, from designs by the speaker,

*Illustrated in *Engineering News* and in *The Engineering Record*, in April, 1902.

at the city dump at the foot of West 47th Street, Borough of Manhattan. Mr. Parsons.

The record of this incinerator is as follows: The number of loads of rubbish brought to the incinerator per day—maximum, 80; minimum, 20; average, 44.2. The 44.2 loads per day weigh about 61 000 lbs., or 30.5 tons. Of this amount about 75%, or 22.87 tons, was consumed; 5%, or 1.5 tons, was incombustible; and about 20%, or 6.1 tons, was trimmed. Much more than 20% could have been trimmed, but the incinerator burned the material so fast that the contractor did not have time to separate it out.

The incinerator contains a grate surface of 90 sq. ft., and the stack is 120 ft. high. The average weight of the material consumed per hour is 5 720 lbs., or 63.5 lbs. per square foot of grate per hour.

The design of the incinerator, in brief, consists of three cells, each having 30 sq. ft. of grate area. The products of combustion pass over the cells into the smoke flue in such a manner that the product from Cell No. 1 has to pass over Cells Nos. 2 and 3; the product of combustion from Cell No. 2 mixes with the products from Cell No. 1 and together they pass over Cell No. 3; and that from Cell No. 3 mixes with the products from Cells Nos. 1 and 2 and is intimately mixed again in passing along a tortuous flue to the base of the stack The result of this arrangement has been highly satisfactory, as regards the non-production of smoke. Taking a stormy day when the material was brought to the incinerator wet, the smoke was seldom visible for more than about 75 ft. from the top of the stack, and then only during the period of stoking one of the grates.

This incinerating plant was constructed as an experiment. In order that it might be free from any hindrance by injunction or otherwise, lest it create a nuisance to neighboring property, it was decided to locate the plant on one of the city piers, about 250 ft. from the bulkhead line. The permanency of location, of course, was not considered, the idea being that if the plant could be constructed quickly and show that combustion could be carried on without creating a nuisance, it would lead to the introduction in the future of other stations, more favorably situated, and at which better facilities could be provided for the reception of the material and for the picking of the same.

The incinerator, thus far, has proved satisfactory, and the Commissioner has authorized the preparation of plans for further developing its capacity.

An analysis of the cost of incineration compared with removal of material by scows is as follows:

First, the Final Disposition by Scows, as Formerly Practiced.—Assuming the same figures as now obtained at the incinerator, namely, 30½ tons of material per day, on the average, the cost of removal of that material, figured at 15 cents for towing, and two days' hire of the

Mr. Parsons. scows, (one for loading and one for towing) at 23 cents, comes to about 38 cents per ton. Owing to the bulkiness of rubbish, only about one-half tonnage can be put upon a scow, the tonnage being figured by volume, which makes the disposal of the material come to something like 80 cents or more per ton by weight. Therefore, 24.39 tons at 80 cents cost the city $19.51 for removal. The 6.1 tons, making up the 30.5 tons, which is saved by the trimmers, at $3.20, also figures $19.52; thus, practically, the cost of removal by scows was offset by the receipts from trimming.

Second, by Incineration.—The result is approximately as follows: Received from trimming 6.1 tons at $3.20, $19.52 per day. Received from the city ash collections, which at this dump amount to about 600 tons per day, and which are made salable at, say, 5 cents per ton when freed from the rubbish, $30.00. Total receipts to the city, $49.52. The cost to remove the incombustible material, 1.5 tons, at 38 cents, 58 cents; cost of burning, interest and repairs on the incinerator, estimated, at $7 per day; labor, feeding and firing, four men, $10 a day; ash removal, $1 a day; total, $18, Net gain, therefore, to the city, $30.94 per day; yearly gain, more than $9 000.

The incinerator, at these figures, will pay for itself within two years. According to the figures quoted by the Commissioner, namely, 19 cents a ton for the ash collections, would make a daily revenue of $114 from the ashes, in place of $30, or a net gain of $114.94 per day, or more than $34 000 per annum; at which rate the incinerator would pay for itself in less than six months.

The ashes produced by the incinerator are very light, completely burned, and, owing to the large quantity of wood from which they are produced, have some value as a fertilizer, and are used by the Park Department for spreading on lawns and around trees.

The improvements referred to are an unloading floor and a belt conveyor, which should increase the amount of material trimmed, that is, the marketable material; and should reduce the cost of labor. Probably the services of two of the men now required could then be dispensed with.

Mr. Morse. W. F. Morse, Esq.—For twelve years the speaker has been actively engaged in the work of final disposal of municipal refuse. It has been his province to present the question in many places and in many ways, and, until now, it must be candidly said that it has not met with appreciation or attention on the part of the engineering fraternity. It has been a question which has fought its way, despite opposition, has been in the hands of men and committees who were really unacquainted with the subject, and has consequently been approached from the standpoint of an endeavor to solve an engineering question without the benefit of the best engineering skill.

Mr. Morse.

The whole subject is a very wide one; it cannot be treated in a short way—by a short discussion—it has to be taken piecemeal and dissected, each part separated and treated by itself.

The remarks of Mr. Hering cover the whole question in a general way. He has given an outline of the various methods of collection, of the disposal, and of the results obtained. The remarks of the Commissioner of Street Cleaning and of Mr. Parsons cover the work done in New York, but there are many other cities than New York investigating this matter, and it is of much wider scope than the limited field of a single city.

In the limited time allowed it is possible to deal with the question only in a very general way, and to give a brief sketch of what has been done in the past ten or twelve years in this country, and, in comparison with that, an idea of what has been accomplished abroad.

Municipal waste has been divided into four classes: garbage, street sweepings, ashes and refuse. The disposal of all these is accomplished by two methods, or systems: reduction and cremation. Reduction, or the treatment of garbage only for obtaining a commercial product, is not now under discussion; but it may be said in passing that this method has been adopted by several of the larger cities, has cost large sums of money to establish, and is yet at a stage where it is impossible to say what its future will be. It is only known that companies and men are putting large sums of money into reduction processes, and that, so far, as many plants have failed and have been abandoned as have succeeded.

If a city is investigating this subject with a view to the disposal of all its waste, and if it adopts a means of disposal which treats only one-tenth of it, there is manifestly left on its hands the remaining nine-tenths. Reduction deals with only 10 or 12% of the whole collected waste of the city, treating garbage only. Cremation, on the other hand, takes the whole collection of miscellaneous waste and disposes of it all.

There have been in the United States, in the last twelve or thirteen years, something like seventy-five or eighty places where cremation has been adopted. This work was begun in Des Moines, Iowa, about fourteen years ago, by a furnace invented by Mr. Andrew Engle, and from which have come all the forms of the American cremator, all more or less imitations of the original Engle type. It is a structure of rectangular form, having an upper chamber and transverse bars on which the garbage is deposited. The fire is at one end, and in most cases the secondary fire for burning the gases is at the other end. In all cases of American crematories two fires have been found necessary, and that principle has been maintained in constructions of this type.

About a month ago, an article appeared in one of the prominent municipal journals under this caption: "Why do American Crema-

Mr. Morse. tories Fail?" The text of that article was a report, made by a leading engineer of this Society, upon a furnace built in a neighboring city, and which was reported to be working unsatisfactorily. In the main essentials, that article is true, and, after twelve years' experience in building garbage furnaces in this country, the speaker is in a position to say that satisfactory progress has not been made; that while one or another type of furnace after the American pattern has been built and has performed its functions, and may be still doing so, the retrogression—that is to say the abandonment of furnaces which have been built after these patterns—has kept pace with the number installed. Therefore, comments, by the newspapers and by prominent engineers, to the effect that the progress of the disposition of waste in this country is not satisfactory, are absolutely true.

Beginning fourteen years ago, with that form of American cremator which was shortly after imitated by other constructions, there have been seventy-five built, and of these perhaps the most widely known and successful installation of the American type was made at the World's Fair in Chicago. This was a case where it was expected that some 50 or 60 tons of refuse per day would be handled, also the sewage sludge which could not be disposed of in any other way. Furnaces, after an improved Engel pattern, were built, and were run six months without intermission, using oil as fuel, and destroying on the grounds of the Exposition, within the confines of one building, all the garbage and all the sewage sludge caused by the presence of 27 500 000 persons, without sanitary nuisance, and to the entire satisfaction of the authorities.

That is an example of what might be done under the best conditions in which an American furnace could work, but that example was never improved upon. The furnaces so built were offered as a gift to the City of Chicago, but they were declined on the ground that they were placed on public property, under control of the State, not the City, and could not be accepted by the City. The results of that demonstration in Chicago show that under proper conditions garbage containing a large percentage of moisture and sewage sludge (two of the most refractory things in the world to deal with by fire) could be destroyed by maintaining a sufficiently high temperature and providing combustion chambers for the destruction of the gases. Unfortunately, this example was never carried much further by that company, but it was acted upon by others, and has been repeated since; yet, in spite of the lessons taught by ten or twelve years of experiment, it may be said that the progress made in cremation work has been equalled by the retrogression in the same line; that furnaces are abandoned about as often as they are built.

There are several obvious reasons for this. The work has been begun at the wrong end. At the outset, a sufficient amount of engi-

neering skill was never applied to it. Municipal committees have gone about the country and have been persuaded by ambitious furnace builders to install plants. These plants have been simply experimental—built for a profit. They were not durable, and required extensive repairs. In many cases they were not sanitary; they emitted odors; they were not in all respects adapted to the work required of them, and they were expensive to operate. Yet, with all their defects, they have made for progress in one particular: they have directed the attention of the people to the fact that something is needed. Mr. Morse.

At the present time there are four or five companies constructing garbage crematories with varying success in different parts of the country. There are at least ten or twelve firms who have gone down—in other words, who have constructed furnaces found to be inefficient—and we are at a stage of the general question of cremation where it is necessary to have some more efficient means brought forward. If progress is to be made, it must be made either by inventing a new furnace, or by adopting other furnaces which have been proven successful elsewhere.

The question arose in England twenty-five years ago, long before it was ever thought of here. It began by the construction of the cell furnace, so-called, the Freyer destructor, operating by the use of a natural chimney draught, no forced draught being thought necessary at that time. The results were almost identical with those of the American furnaces of to-day. The temperature was low, offensive gases were thrown off, notwithstanding the "fume-cremator," or secondary fire, and it was found expensive to maintain. No real progress was made until about four or five years ago, when the furnace was shortened, forced draught introduced, the sloping platform made in such a shape that the garbage could be used as part of the fuel, and a combustion chamber added, behind which a steam boiler was placed.

The English destructors are to-day one of the most powerful agencies for sanitary conditions in England. They take what is known here as municipal waste, as a whole. No separation is made; the entire waste of the household goes into what is called an ashpit, or ashbin—garbage, refuse and ashes—and this is taken directly to the destructor and burned. It is destroyed under forced draught, with no other fuel needed than the material itself. The result is the production of a volume of heat which operates steam boilers of very great capacity, the power from them being utilized for the production of electricity, for pumping sewage and water, and for many other municipal purposes.

The comparison between English and American efficient disposal work is distinctly against us. We are doing as they did six or eight years ago. At the present time there is no English destructor on this

Mr. Morse. continent. The Thackeray furnace is an attempt. It is really an imitation of the principles of the Freyer destructor which was built many years ago in England, and which has now almost passed out of date, being supplanted by more powerful ones. There are two examples of this furnace, one in Montreal and another in San Francisco; but in the last five years, since these furnaces were built, no others have been installed, and there has been little attempt to develop more fully the English ideas.

The chief reasons for this lie practically on the financial side of the question. The cost of the construction of a destructor is about one-half more than the cost of an American cremator of equal capacity, and municipalities are usually looking first to the dollar and second to the sanitary operation and to the comfort of the people.

The following figures are quoted from the latest information regarding the operation of the English destructors. The comparative results from twenty English destructors, of eight different types, with thirty-two tests made for evaporation at different periods, shows that the average combustion per square foot of grate surface is 47 lbs. of mixed waste, garbage, ashes and refuse, and the evaporation of 1.36 lbs. of water for every pound of waste consumed. Therein lies the secret of the progress made in England. When they put into their destructors a mixed mass of material and burn it under a forced draught and develop steam power which is equivalent to the evaporation of 1¼ lbs. of water for every pound destroyed, the enormous force produced can readily be seen, the utilization of which has made it possible for every municipality to do its work with its own power, without other fuel than the material destroyed, at a very small cost as compared to the cost of operation on this side of the water.

The cost of labor for destroying a ton of mixed refuse will run from 12 cents to 30 cents per ton, dependent upon local conditions. In one place the work is carried on at a profit; in others, the returns from the destructor, in steam power and in products manufactured from ashes, pay all operating expenses and fixed charges. The residuum from these furnaces is a valuable asset. The clinker is ground up and made into mortar, or tiles, paving blocks and brick.

There is another item on the credit side of the destructor, that is the utilization of power developed by the combustion of municipal waste for use in electricity works.

There are about 160 places in Great Britain in which destructors are used, and more than two-thirds of these utilize the power for various purposes. The electric force developed by a destructor which burns the waste product of a city is equivalent to 30 British Board of Trade Units per ton of waste destroyed. If it be assumed that each unit is equivalent to 280 candle-power, the result is something like 8 400 or 8 500 candle-power from each ton of waste.

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The chief reason why advance in disposal work in that country has been so rapid and efficient is the fact that English municipalities proceed upon a different plan from ours. They make it a part of their municipal work. In this country it is contract work, and, consequently, there is not the same opportunity for cities to develop along the lines of municipal ownership and administration. There is a strong desire on the part of municipalities to adopt these improved methods, but they are held back by the fact that in almost every case the contract takes precedence, and the contractor is desirous only of getting through with his contract, and the same results are not accomplished as when the work is done by the municipality.

The remarks made by the Commissioner of Street Cleaning and by Mr. Parsons upon the work in New York City are pertinent and apropos of the question, but they do not cover the country. The principles which Dr. Woodbury is carrying out were instituted by Colonel Waring five or six years ago, and the experiments made at that time showed conclusively that the value of the rubbish of New York City was greater by far than anyone had supposed. The statement made by Colonel Waring in one of his last reports, that the value of the refuse, garbage and ashes of New York City would, if properly utilized, pay one-half of the total expense of cleaning the city, has never been realized. Yet it is certainly a question which is being answered by the present administration in a very satisfactory way. The Commissioner has alluded to, and Mr. Parsons has described, an incinerator, for the conversion of refuse, at West Forty-seventh Street.

The speaker had the honor of presenting this question to the Mayor of Boston four and a half years ago, proceeding largely upon the lines marked out by Colonel Waring, and at that time it was believed that the utilization of the refuse would become a feature of very great importance in municipal work. Mayor Quincy looked into the matter personally. He called for specifications and bids; he obtained four or five bids which were unsatisfactory, and rejected them. He took the plans which were offered for the construction of an incinerator in Boston, and caused it to be erected by a private company. The incinerator is quite different in pattern from the one described by Mr. Parsons, but for four years it has been burning the refuse of the business section and a large part of the residential portion of the city, taking the waste from about 200 000 people, covering about 95 miles of streets, brought to one central point. The waste is carried into a room and dumped upon a moving platform, or belt, 150 ft. long, and during its passage the refuse is picked over by men placed on each side. These sorted portions pass into bins and presses below, and the remainder is discharged automatically into a destructor, or incinerator, placed across the end of the building. The quantity of waste destroyed began at about 25 tons per day for the first year, and it has increased

Mr. Morse. until now about 40 tons per day are collected and disposed of. The product which is picked out from the refuse by these men will reach very nearly 60% of the whole bulk. It is divided into six or seven classes of paper, five kinds of rags, rubber, glass and iron. Everything possible is sorted out and saved, and the residuum destroyed are the small, worthless portions of paper, excelsior and straw, and a small amount of wood. The operation is conducted precisely as it should be conducted in New York City, in a closed building, the city carts discharging their loads out of sight of passers-by, no nuisance of any sort being connected with the work. After baling, the salable portions are at once conveyed to market, and the power produced by the combustion of the worthless portions of the refuse drives a 60 H.-P. boiler to its utmost capacity, which in turn moves all the machinery, lights the building with electric light, removes the ashes, heats the building in winter, and, thus far, has furnished a surplus of steam power.

The operation of this plant for four years shows that the refuse of a city of the size of Boston is more valuable than almost any other part of the municipal waste, and that every city with a population of 50 000 or upward can easily turn its refuse into money which will go a long way toward paying the expenses of the whole collection service.

Other cities are considering this question, with the idea of bringing into use a system similar to that which has been carried on in Boston, and which has just now been reinaugurated by the Commissioner of Street Cleaning in New York City, and which will undoubtedly be a factor in the disposal work of all cities in the country.

The average quantity of refuse collected is about 1 ton per day for every 10 000 persons. It may be more or less according to the different character of the city and the population, but it is of sufficient value to pay for the installation and operation of a plant in any one of the larger places in the country.

The future of this question depends upon utilization. American crematories have been going on for ten years, destroying garbage by using coal. The builders, up to this time, have paid no attention to refuse and its salable and fuel qualities. They have allowed the heat produced by the combustion to go to waste; and they have not been over-desirous of guarding against sanitary nuisance, but have sought to destroy the waste in the shortest possible time, without considering the economical points involved.

There is a general impression that a change must be made before real progress can be had, and there is hope that the engineering profession throughout the country will take up this question, as has been done abroad, and bring its trained experience to the assistance of the municipalities, solving the question in a much shorter and easier way than it can otherwise be done. It is inevitable that this will come

about. The men who are trained in constructive and operative work should be the ones to decide what shall be done in this line by every city. Mr. Morse.

There is another side to this matter which is pertinent to the question under discussion. That is the disposal of the waste of large isolated buildings, like public institutions of every class, hotels, business establishments and even individual dwellings. The quantity of waste produced in these places is proportionately larger than under other conditions. There is now in use a form of destructor, installed usually in the basement of the building, connected with the boiler breeching, or the chimney. These destructors are used for the disposition of every class of waste, including that from laboratories and medical colleges.

The latest examples of these furnaces have been built in connection with the steam boilers of large business establishments, where the heat from the enormous mass of waste destroyed is used as auxiliary for operating the boilers. In some cases the destructor is also provided with a separate steam boiler operated by the furnace, but supplied with its own fire box, the power from which is utilized for specific purposes, like running elevators, or in connection with the low-pressure steam system of the building.

The advantages to be obtained by the introduction of these local destructors are the disposition of the waste on the premises in a perfectly sanitary manner without the necessity of storing and handling the same, and the development of a certain amount of steam power, resulting in the saving of coal, or other fuel, and to some extent expense in steam boiler equipment. These destructors are also being adopted by the Government for use in Army and Navy posts and government buildings throughout the country.

The number of these destructors in use, already quite large, is increasing rapidly, as the installations are made under the direct inspection and by the advice of competent architects and engineers engaged in the construction work.

GEORGE A. SOPER, Assoc. M. Am. Soc. C. E.—The question of the sanitary disposition of municipal wastes is often divided into two parts: Final disposition, and collection. Mr. Soper

By final disposition is meant the utilization or simple deposit of wastes; and by collection is meant all other steps in the operations of a street-cleaning department. It is not uncommon, in discussions on this topic, to omit that part of the subject which relates to collection; but, as the two questions are inseparably related in practice, it seems desirable that they should be treated jointly.

To a large extent, the method chosen by a city for the final disposition of its refuse is a controlling factor in the organization and plant of its street-cleaning department. This has been so in New York City.

Mr. Soper. The history and development of the Department of Street Cleaning in New York City affords many interesting suggestions as to the relations between final disposition and collection, and the experience of that city furnishes, withal, such an instructive illustration of the need of keeping the various parts of the machinery of the street-cleaning department in harmony and up to the requirements of a rapidly growing municipality, that some extended reference to it may be useful.

The organization of the Street-Cleaning Department, as a separate branch of administration in New York City, dates from the year 1881, up to which time the collection and disposal of wastes was carried on under the direction of the Department of Police. The new organization was the outcome of much agitation on the part of the public; physicians and political reform associations taking an active part in the crusade.

For ten years after its formation the Department did little to justify its existence. On the contrary, it became such an object of dissatisfaction that, in 1891, it was determined to appoint an Advisory Commission to inquire into the defects of the organization and to recommend measures of improvement.

The Commission was named by Mayor Hugh J. Grant, and consisted of five citizens, among whom were two business men, a lawyer, a sanitary expert and an engineer, the last being a member of this Society.

The report of Mayor Grant's Commission marked an epoch in the history of the Street-Cleaning Department of New York City. It is, moreover, so remarkable a document, from the clear and exact way in which the faults and needs of street-cleaning departments in general are defined, that a summary of its findings is here given:

In the first place it was declared that the department was not efficiently managed, as judged by standards of management of well-established corporations engaged in large enterprises.

One source of difficulty lay in the methods of employing labor. The laborers themselves were inefficient, and owed their positions to political influence.

The plant of the Department was poorly located.

The plant was insufficient.

There was a lack of proper organization and disposition of forces.

The manner of disposing of refuse was not satisfactory.

The law under which the Street-Cleaning Department was conducted was adequate, provided it was efficiently administered by a Commissioner who had the cordial co-operation of the Mayor, Police Justices, Department of Health, Commissioner of Public Works, and Board of Estimate and Apportionment.

The annual appropriation was insufficient.

The police should help to keep the streets clean.

There should be rules for the employment of men.

Mr. Soper.

It was observed that the management of the Street-Cleaning Department required the same kind of ability as the management of a transportation company, or other large corporation employing a considerable number of men.

The report of Mayor Grant's Commission, one of the most forcible and lucid papers on this topic which the speaker has ever read, is the foundation upon which the present organization of the Street-Cleaning Department is based. The practical effect which the report had was a reorganization of the Department by legislative enactment in 1892.

Unfortunately, the opportunities thus opened for developing an efficient system of street cleaning were not at first realized. The first thing done in accordance with the recommendations was to increase the appropriations. Then progress ceased. The Department promised to remain as it had always been, an organization in which political influence was carefully and continually fostered.

By the time Mayor Strong's reform administration of 1895 came into power it was apparent that there was need of a strong head to develop the possibilities of improvement contemplated in the legislative act of reorganization. It is now a subject of universal satisfaction that such a head was found by Mayor Strong when, in 1895, he appointed the late Colonel George E. Waring, Jr., Commissioner of Street Cleaning. Whatever may be said of Waring's career, as an engineer or sanitary reformer, it must be admitted that in the three years during which he held office as Commissioner of Street Cleaning he made comparatively few mistakes and reached the greatest success, in raising the standard of usefulness of his Department, that New York City has ever known.

At the same time, it is not to be denied that circumstances favored Waring. A large part of his success was achieved on lines laid down in the report of Mayor Grant's Commission of 1891. Waring also had the advantage of a report of a Legislative Committee of investigation and advice appointed by Mayor Gilroy in 1894. The report of Mayor Gilroy's Committee, dated November, 1894, recommends that:

First.—Dumping city refuse in the harbor or its tributary waters should be absolutely prohibited.

Second.—The ordinances requiring householders to keep separate the garbage, or kitchen refuse, from ashes and other house refuse should be rigidly enforced.

Third.—All house refuse should be collected in galvanized iron vessels with tight-fitting metal covers, of such size that, when full, they can be handled by one man.

Fourth.—Daily collections of garbage should be made by the City and delivered at dumping wharves into temporary storage, or self-

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propelled boats of some approved type to be furnished by the party having the contract with the City for the final disposition of the garbage.

Fifth.—The garbage should be disposed of by a reduction process producing fertilizer and commercial grease; and the City should invite competition by the various companies controlling such systems, in order that the greatest benefit to the City may result.

Sixth.—A separate collection should be made of the remainder of the refuse of the City "not otherwise provided for," which should be used for filling Riker's Island, or elsewhere; and, for transportation of this material, a sufficient number of self-propelled boats of approved type should be constructed and owned by the City. It should be provided, however, that whenever the whole, or any considerable portion, of the street sweepings can be disposed of by contract or sale for fertilizing purposes, at a price greater to the City than the value for filling, then such disposition should undoubtedly be made of them.

A careful reading of the foregoing recommendations will reveal on the one hand some excellent advice and on the other some stipulations which had the effect of committing the City to a particular process of garbage destruction and the plan of disposing of garbage by contract with a private company.

Some prominent reforms introduced by Waring were: Improved methods of administration; insistence that the laws and ordinances relating to cleanliness and order in the streets be enforced; and improvements in methods of collecting and disposing of the wastes. A large part of Waring's success, as the head of the Street-Cleaning Department, was due to his remarkable power of instilling a spirit of industry among his men. It has been well said that he found the force of sweepers and drivers a laughing-stock and left them a body of honored workmen.

It is well known that, after reorganizing his working force, Waring's ambition was to devise means for the economical, if not profitable, final disposition of the City's refuse. Up to Waring's time, the ashes, paper, garbage, and other refuse of the city had been collected and carried in a mixed condition to points along the water front where it was picked over by Italians, who had the privilege of extracting bones, bottles, rags, metals, and other salable matter. This privilege was purchased from the City annually, and in 1894 amounted to $140 000. The residue left over after the picking was taken by scows and dumped at sea or used to fill in low lands in the neighborhood of the City.

Under Waring, the City wastes were separated, as is the custom to-day, into three classes before collection; notably, garbage, ashes and

paper. Experimental studies were made of the value of these different kinds of refuse. Garbage was also collected from other cities, and the value of its grease and other constituents carefully determined. According to estimates, made at the time of these studies, the average quality of garbage produced in New York City was worth $2.47 per ton. Mr. Soper.

A practical plant for the separation of the utilizable ingredients of refuse, other than garbage, was erected and operated for many months. The sale of the bottles, metals, rags, paper, and other useful materials, thus collected from 31 300 tons of refuse, netted the City $3 680. A considerable amount of useful steam-power was also generated at the same time.

It is a lasting source of regret that Waring's term of office was too short to enable him to complete the development of a plant whereby all of the wastes of the City could be disposed of profitably, or at least inoffensively. Just as his investigations were pointing to positive and permanent reforms his term ceased.

At the end of Waring's administration the efficiency of the Department immediately fell. The Commissioners who followed seem not to have been suited by talents or experience to conduct the Department on the plane of efficiency which Waring had initiated. Negligence, extravagance—some have said, corrupt practices—crept into the affairs of the Department. A single illustration will suffice to convey the speaker's meaning. The following extract is taken from page 24 of the Annual Report of the Department of Street Cleaning for 1900:

"In September, the New York Sanitary Utilization Company complained that it was not receiving all the garbage to which it was entitled by the terms of its contract with the City, on account of faulty separation, and claimed that the scow-trimming contractor was culling bones and grease for sale to which they, the New York S. U. Co., were entitled, and to which the scow-trimming contractor, by the terms of his contract with the City, expressly denied any claim or right. The matter was finally compromised by the Department paying to the scow-trimming contractor sixty cents per barrel for bones and one and three-quarters cents per pound for grease collected from the ashes, which was turned over to the Sanitary Company. This arrangement resulted in a continual increase week by week in the quantity of this material collected from the ashes and street sweepings, so that for the last week in December the Department's payments to the scow-trimming contractor amounted to $2 127.41."

The charter of Greater New York, which went into effect in 1898, added much to the responsibility of the Street-Cleaning Commissioner, and complicated the unsolved problems of his imperfectly developed department. The plant of the Department should have been increased and the organization properly expanded to meet the requirements of the Greater City, but it is clear that no such logical development was contemplated.

Mr. Soper. The unsatisfactory condition of the streets of New York City at the beginning of the present administration is well known. Many of the innovations and improvements introduced under Waring were discontinued and forgotten. Much of the plant was out of order and some of it out of service. Two self-propelled refuse barges were laid up, apparently for no other reason than that they were too economical. Horses were out of condition, overworked, poorly cared for. The dumps and docks were in a disgracefully insanitary condition. The force of laborers was demoralized. The streets were filthy. The rules of the Department, and especially the City ordinances, were shamefully neglected. The policy of entering into contracts with private parties had been extended. The method of letting contracts was open to severest criticism. A contract for the disposal of the garbage of Manhattan had to be let at an exorbitant figure because bids were not called for until too late to secure profitable competition.

Were it not that commerce, convenience and health demand that the collection and disposal of the City wastes be carried on in an efficient manner, the great cost of the Department of Street Cleaning would furnish a sufficient reason why its work should be well done.

The City Budget for 1903 calls for an expenditure of nearly $5 400 000 to pay the running expenses of the Department of Street Cleaning. No other Department of the City Government, except the Departments of Police and Education, spend so much money. The annual cost of the Department of Street Cleaning exceeds the cost of many other Departments combined.

It may be profitable to consider for a moment the chief items of expense, as shown by the Annual Reports of the Commissioners of Street Cleaning:

First: Sweeping.—By this is meant the collection of dirt, etc., from the pavement. This item, in the year 1901, for Manhattan and the Bronx, amounted to $1 402 056.82.

Second: Cartage.—This includes the hauling of refuse material, such as garbage, ashes, paper, and other like refuse. Carting, in 1901, in Manhattan and the Bronx, amounted to $990 577.71.

Third: Final Disposition.—This means the reduction of garbage by contract, dumping of ashes and other dry refuse to fill land, and sea dumping. In 1901, final disposition, for Manhattan and the Bronx, cost $733 602.01.

Fourth: The Removal of Snow and Ice from the Streets of Heaviest Traffic.—This item, in 1901, is said to have been about $600 000.

Fifth: Administration.—Administration cost $223 456.62, in Manhattan and the Bronx, in 1901.

Sixth: Rents and Contingencies.—For Manhattan and the Bronx, this item amounted to $121 490.07 in the year 1901.

The total sum represented by the foregoing items is $4 071 183.23. Mr. Soper.

From the reports of Mayor Grant's Commission, and the Commissioner of Street Cleaning for 1900, the expenses appear to have increased out of all proportion to the quantities of refuse removed. The figures are as follows:

Year.	Appropriation.	Loads of Refuse.
1882.....	$1 010 000.....	1 116 360
1890.....	1 280 525.....	1 702 102
1900.....	5 584 100.....	2 602 120

But the cost of the Street-Cleaning Department, as shown by the official reports, does not represent the total cost to the citizens for removing and disposing of the City's refuse. Other items of expense are the removal of dead animals from the streets, the removal of manure from stables, the removal of market refuse, the removal of cellar dirt, and the sprinkling of streets.

The largest extra is for private carting. An immense number of property holders employ private scavengers. Hotels, office buildings, apartment houses, restaurants, manufacturing establishments, retail dry goods shops, and many residences are compelled to remove their wastes at their own expense. Recently, even the privilege of the City dumps has been denied to cartmen, and it is said that in some cases refuse has had to be hauled several miles and carried across ferries for disposal.

The total expense of the extra scavenging work made necessary by the inability of the Street-Cleaning Department to collect and dispose of our municipal wastes in a satisfactory manner is very large. In 1891 the sum paid for the private collection of refuse was estimated to be between $150 000 and $175 000. It is now very much larger. The quantity of refuse of various kinds dumped at City wharves by private carts has been more than 30% of the total quantity collected by the Department of Street Cleaning. In addition, more than 100 tons of swill per day are carried out of town to be converted into soap, or fed to cattle and swine.

In reply to a request from the Board of Aldermen, for a specification or draft of the organization necessary to handle the output of refuse of the large office buildings, stores and places of business which now employ private scavengers, the Street-Cleaning Commissioner said, a few days ago, that he would require 500 additional horses, 500 carts, 500 drivers, 50 hostlers, three stable foremen, three assistant stable foremen, nine stable clerks, twenty stablemen, proper stabling for the horses, and spaces for the carts, together with such equipments as harness, blankets, buckets, etc., and proper water-front facilities for the handling of this material. The total number of carts and trucks now under the Commissioner, in Manhattan and the Bronx,

Mr. Soper. 744. By making his request for 500 more carts, the Commissioner tacitly admitted that 40% of the work of removing refuse in New York is now done by means outside of his Department and beyond his control.

The private collection of refuse is objectionable, from every point of view. It leads to insanitary practices, and is an item of expense and annoyance from which the taxpayers of the City should be free. The cost of private collection is not equitably distributed, but is often heaviest upon those who pay the largest taxes. But there is no use in emphasizing the evils and extravagances of the present situation. If the force, plant and organization of the Department of Street Cleaning were adequate to the needs of the City there would be no excuse for them.

If the foregoing remarks carry any clear idea, it must be that the work of collecting and disposing of the wastes of the metropolis is badly done. Such efficiency as exists is due largely to the energy of the present Commissioner and the effects of the two notable epochs, in the history of the Department, to which reference has been made. The first of these epochs was the investigation, report and reorganization due to Mayor Grant's Commission. To this may be added the investigation and the improvements suggested by the Committee of Advice appointed by Mayor Gilroy. The second epoch was marked by the tenure of office of Colonel Waring.

In the history of the Department, few, if any, important reforms or developments have been made which were not the result of seeking outside investigation and advice. Is it not time that the disposition of the City's wastes be again made the subject of an exhaustive inquiry?

At the present moment the City is deplorably dirty. Business men and property holders are complaining that their refuse is not removed, and an immense sum of money is being spent for the collection and removal of wastes which, upon theoretical considerations, are valuable. The Street-Cleaning Department is struggling under the disadvantages of an imcomplete and outgrown equipment. It may seem like strong language, but it is not beyond the facts, to say that the system of cleaning the streets of the metropolis, if followed by a private corporation, would lead to bankruptcy.

The speaker intends no unfriendly criticism of Dr. Woodbury, our able Street-Cleaning Commissioner, in stating that the length of his term and the power of his office are not sufficient to enable him to correct, single-handed, the mistakes of the four years of mal-administration which preceded him, and place the Department on the efficient footing which the citizens have a right to expect. To meet the changed conditions due to the recent phenomenal growth of New York City, the Department needs to be developed, expanded and made as efficient as it was in Waring's time.

The speaker sees only one way by which these ends may be accomplished, and that is through the work of a Commission of Investigation and Advice, such as was appointed by Mayor Grant. Mr. Soper.

In the speaker's view, the most important specific problem pressing for solution is: How shall the City's wastes be finally disposed of? This is the keystone of the great question as to the best means of organizing and equipping the Department of Street Cleaning.

Second.—Another query is: Is it well for the City to enter into contracts with private individuals for horses and carts to collect the refuse, for barges to remove it to a distance and for reduction works to dispose of it?

Third.—One more question is: How can the ordinances relating to the careless littering of streets and the separation of refuse be enforced?

Fourth.—Finally: In what ways and to what extent should the plant of the Department be increased?

Without desiring to amplify this last interrogation unduly, or to presume to possess the knowledge required to answer it, the speaker would state that it is believed, by those who have taken an intelligent interest in the Department, that more and better dumps are needed; more and better scows are needed; more and better carts and horses and stables and stations are needed; and refuse destructors or garbage crematories, built in accordance with the best known practices, are needed. In addition, very possibly, street-sweeping machines and snow-melting machines are needed.

It should not be an open question whether mechanical devices cannot, to some extent at least, replace the hand labor which is now the chief item of expense in cleaning the streets.

The present moment is propitious for an investigation. The existing administration is pledged to municipal reforms, and has executed or planned several admirable lines of improvement. The present Street-Cleaning Commissioner has demonstrated, by a year's administration of his office, that he has the capacity, energy and determination to put in force such measures of relief and permanent improvement as may be placed within his reach. The work of the Commission which the speaker suggests would greatly facilitate his efforts to bring the plant and organization of the Department to a high state of efficiency.

It is a pleasure to say that the plan of appointing a Commission has received Dr. Woodbury's endorsement, and that Dr. Lederle, President of the Board of Health, has given it his approval.

THEODORE HORTON, Assoc. M. Am. Soc. C. E.—The Trenton garbage plant was a source of serious trouble during last summer (at a time, in general, when such plants give evidence of any defects in design or management), and a consulting engineer was called upon to investigate Mr. Horton.

Mr. Horton. and make a report to the City in regard to it. He was asked, first, to determine the nature and extent of the trouble, and, secondly, to make such recommendations as might be needed to relieve the situation.

The details of the work, in a great measure, devolved upon the speaker, and he will describe briefly what occurred during his visit.

The plant, which, unfortunately, was located in the midst of a thickly settled district, consisted of two Davis destructors connected with a stack 120 ft. high. Each furnace consisted of a combustion chamber; a drying chamber, below which was located an evaporating pan; secondary fire grates; a flue of somewhat contracted area leading to the chimney; and a set of screens to intercept dust particles.

The speaker spent the first day in familiarizing himself with the construction and operation of the plant, and in getting under headway a systematic record of the various features which would lead to a solution of the trouble. These consisted of a record of weights of garbage consumed, coal burned, and ashes; the times of delivery of garbage, charging of furnaces, firing, cleaning grates, operating dampers, and such other observations as might throw light upon the causes of the trouble.

While these records were being kept by the various employees of the plant, other observations, of a special nature, were carried on under the speaker's personal supervision. Thus, he made several analyses of the garbage, which in this particular case was a very important element, due to the fact that it was that known as kitchen garbage, or swill, and was free from ashes. At that season of the year, it was practically saturated. These analyses were simple, and consisted of merely assorting samples, of about ½ ton each, into various parts and weighing them. The garbage was found to consist of 84% animal and vegetable matter, 12% paper, 3% rags, carpets, etc., and 1% boxes, barrels and other rubbish; 80% of the whole being water.

Other observations were made to determine the extent of the trouble arising from the dust particles which, emanating from the stack, were causes of much annoyance to the residents of the neighborhood, and of alleged fires in the immediate vicinity of the crematory.

The observations made during the daytime were simple in nature, but served at least to give a tangible idea of the actual conditions. They consisted of observing, at various distances from the crematory, and in the line of smoke from the stack, the number of particles passing a vertical plane in a given time. The distances selected were ¼, ½ and ½ mile, and the interval of time 15 minutes. The particles were from ⅛ to 1 in. equivalent diameter, and of course were plainly visible.

In order to present this source of trouble in a still different light,

Mr. Horton.

other observations were made by selecting places in the open fields, at various distances from the crematory, and counting the number of particles deposited on an area of 50 sq. ft. During both the foregoing sets of observations, which covered a period of about 3 hours, the wind had been blowing steadily from the same quarter, so that, considered as a whole, the record really had a comparative value, notwithstanding its approximate nature.

In order to get some idea of the danger caused by these dust particles as regards the alleged fires in the vicinity, observations were made upon the glowing embers emitted from the stack at night. Thus, it was observed that:

First.—No embers were seen in a state of actual flaming.

Second.—Glowing embers were emitted principally at times when the furnace doors were open for firing, raking or cleaning.

Third.—During these times it was estimated that, on an average, 50 to 100 sparks were emitted per minute. Of these, it was estimated that 50% did not travel, in a glowing state, further than 25 ft. from the top of the stack; 90% not more than 50 ft.; 95% not more than 75 ft.; 99% not more than 100 ft. and an occasional spark from 150 to 200 ft.

In studying the question of internal combustion in the furnaces, other observations were made, to supplement the general record kept by the employees. These, however, were mostly of a superficial nature and hardly admitted of any refinement, except, perhaps, a determination of the temperature of the flue gases, and even this was somewhat approximate. The speaker had suspected that the temperatures were very low, and at first had tried 500° mercurial thermometers, but, after breaking two of these, and not being able to obtain a pyrometer, he resorted to the somewhat crude method of exposing in the flues metals having different melting points. By a system of elimination, these experiments indicated a temperature of between 800 and 900°, which was sufficiently close for the desired purpose.

At the end of the week's run, the foregoing records were tabulated and studied, and the following is a summary of the results:

RESULTS OF OPERATION OF GARBAGE CREMATORY AT TRENTON, N. J., FOR THE WEEK OF AUGUST 4TH–9TH, INCLUSIVE, 1902.

Total garbage burned	188.0 tons.
Garbage burned per day	31.3 "
Coal used on main fires	10.7 "
Coal used on auxiliary fires (estimated)	3.0 "
Total coal used	13.7 "
Coal used per day	2.3 "
Garbage burned per ton of coal	13.8 "
Approximate average time of burning each day	14.0 hours.

Mr. Horton.

Equivalent number of days of 24 hours	3.5 days.
Equivalent garbage burned per square foot of grate area, per day of 24 hours	1 080 lbs.
Equivalent amount of garbage burned per cell of 25 sq. ft., per day of 24 hours	13.5 tons.
Estimated total amount of clinkers from garbage and coal grates	14.0 "
Estimated amount of ashes from below grates	3.0 "
Estimated total amount of ashes and clinkers	17.0 "
Percentage of ashes and clinkers to garbage burned	9.1 per cent.
Range of temperature of flue gases in stack	600°–1 000° Fahr.
Percentage of moisture in garbage	81.0 per cent.
Corresponding water evaporated daily in furnaces	25.5 tons.
Quantity of coal required per day to evaporate this water, on a basis of 10 lbs. of water per pound of coal	2.5 "

A discussion of all the questions involved in the investigation of this plant has been embodied in the report of the consulting engineer, and as this has already been published elsewhere in full, the speaker will give merely a brief abstract of the conclusions reached and the recommendations made to the City, as follows:

" 1.—Notwithstanding the existing defects and the criticisms which it has been necessary to make, the Trenton furnaces belong to the better class of such plants in our country, and the troubles and nuisances with which you are now contending, are also more or less common elsewhere.

" 2.—The collection in well-constructed metal carts, such as you have, and also the frequency of your collections, are quite satisfactory. It may be suggested, however, that provisions for thorough cleaning of the carts after dumping would be a still further improvement.

" 3.—To obviate the nuisances of dust escaping at the stack, either from well-burned or unburned garbage, it is necessary, after securing perfect combustion, to introduce a dust-settling chamber of proper size between the furnaces and the stack, containing baffles and properly placed inlets and outlets. The screens now in the chimney, although useful as a safeguard against accidental emissions of light but large matter, are insufficient to retain all of the matter now escaping from the furnaces.

" 4.—To reduce further the possibility of unburned particles escaping through the stack, it is important to place dampers in the flues leading from each furnace, as well as in the chimney, so as to afford control of the drafts at all points where and when it is needed.

" 5.—The garbage now delivered, when properly drained and carefully burned in a well-designed furnace, is readily combustible, and should not require the addition of as much coal as now used; and at some seasons, except to start fires, and, otherwise, on rare occasions, perhaps no coal may be required.

Mr. Horton.

"6.—We find that the furnaces are not sufficient in size to effect a complete destruction of the material during the hours of the day when the crematory is operated. Continuous firing for 24 hours can relieve this sufficiently. To this end it would be necessary to store the material for a part of the day, and this could not be objectionable in any way.

"7.—To secure a complete combustion of the garbage, more economically than at present, the design of the furnaces should be somewhat altered. The horizontal grates are not the most suitable for the material, which must first be dried, and then with difficulty pulled from one position to another for burning. A sloping grate for burning, and a sloping floor for the drying chamber, from which the material can be gradually and almost automatically moved from the feed-hole to the hottest portion of the fire, permit of a better utilization of the heat, and reduce the difficulties of stoking.

"These recommendations, supplemented by a systematic attention and skillful practice on the part of the Superintendent and his subordinates, would enable them to operate the crematory so that nuisances from odors and dust would cease."

Mr. Firth.

ELMER W. FIRTH, Jun. Am. Soc. C. E. (by letter).—The use of public dumping places within the city limits is an important phase of refuse disposal as applied to New York City. In the Borough of Brooklyn, for instance, there are deposited at these places, not only ashes, but the dust and dirt gathered from public and private buildings and conveyances, the soiled sawdust from wooden cuspidors, street sweepings, and much garbage and other refuse. Much of this deposit is subsequently blown about the streets in the vicinity, and the Health Department has received many complaints as to the frightening of horses, and other unpleasant experiences resulting from flying papers, etc., from these dumps.

The transportation of such large material suggests a greater distribution of dust and dirt through the air in these localities, and, possibly, an increased morbidity or mortality due to this condition. Figuring the average diphtherial death-rate in Brooklyn, by wards, from statistics in the Health Department reports for 1895 and 1896, it was observed that this death-rate was higher in the vicinity of the public dumping grounds than in other sections of the city. The writer hesitates to mention this as more than a coincidence, admitting that the relative number of cases of sickness would be a better basis for comparison. Then, also, it may be said that as these dumping places are generally located in the poorer sections of the city, scanty or inefficient medical service would increase the number of fatal cases in these localities; but against this argument may be placed municipal supervision, quarantine and the free distribution of anti-toxine.

It should be noted that in diphtheria the seat of infection is in the respiratory passages. The bacillus recognized as its cause withstands prolonged drying, and may be carried through air in a virulent condition. While it is not claimed that this specific disease is transmitted

Mr. Firth. directly by the dust blown about, from these deposits of refuse, yet a predisposition to it may result from constantly inhaling such impure air.

Even if the deposition of such refuse is not proved to be accountable directly for much of the suffering in these places, it at least maintains an unsanitary condition in the very communities where the death-rate is highest and in the midst of classes least capable of avoiding infection or of curing disease.

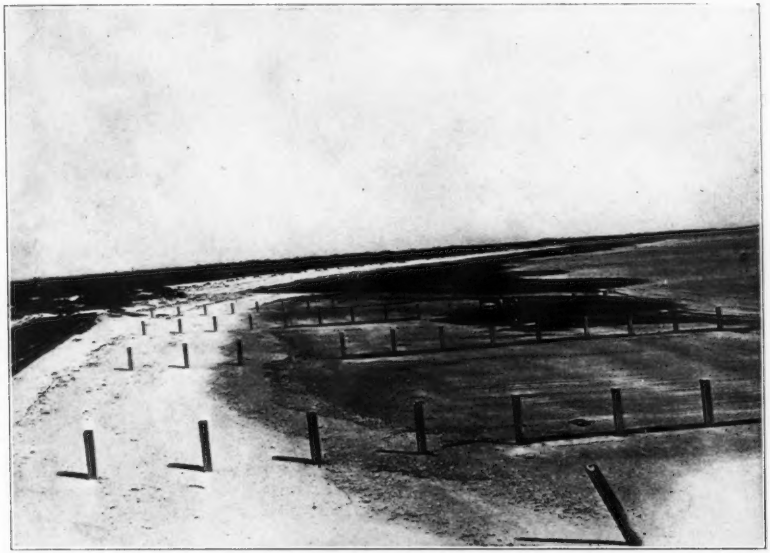


FIG. 1.—BEACH, WITH GROYNES IN POSITION, JUNE 27TH, 1902.

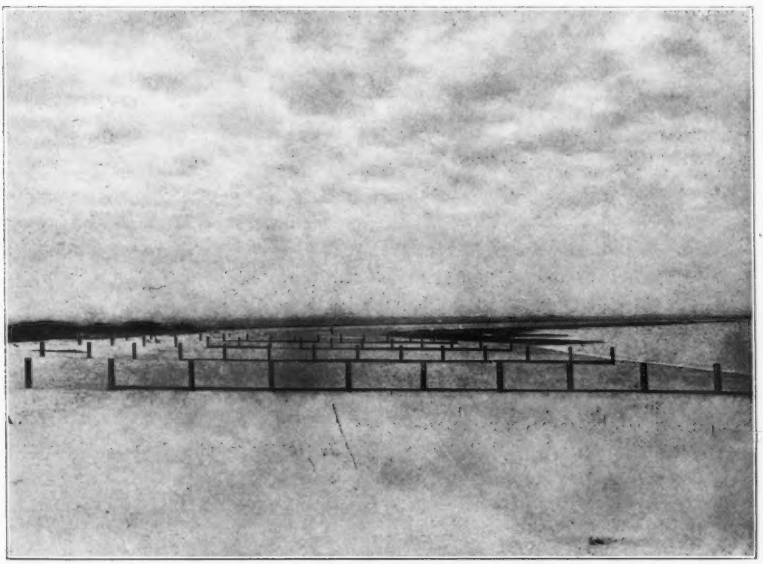


FIG 2.—BEACH, ON DECEMBER 20TH, 1902.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE PROTECTION AND IMPROVEMENT OF FORESHORES BY THE UTILIZATION OF TIDAL AND WAVE ACTION.

Discussion.*

By E. Burslem Thomson, Assoc. M. Am. Soc. C. E.

† E. Burslem Thomson, Assoc. M. Am. Soc. C. E. (by letter).—Two photographs of the groynes mentioned in the writer's previous discussion‡ are shown in Plate XIII. Fig. 1 was taken on June 27th, 1902, when the first tier of planks and some few of the second tier had been set in place. These show the irregularities of the beach, as well as the dark patches of marsh mud. Fig. 2 was taken on December 20th, 1902, shortly after the third tier, and in some parts the fourth tier, had been placed. The improvement in the slope and the disappearance of the mud patches, as well as the general rise in elevation, are indicated clearly in these views. Mr. Thomson.

Beyond the region of action of the groynes the mud flats still exist. It is to be noted that the first four posts from the face of the timber dam are not brought into use, the groynes commencing at the fifth post.

* Continued from November, 1902, *Proceedings*. See August, 1902, *Proceedings*, for paper on this subject by R. G. Allanson-Winn, M. Inst. C. E., I.

† This part of Mr. Thomson's discussion was contributed subsequently by him.

‡ *Proceedings*, Am. Soc. C. E., November, 1902, p. 810.

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VIRTUAL GRADES FOR FREIGHT TRAINS.

Discussion.*

By Messrs. C. D. Purdon, F. H. Hebblethwaite, William G. Raymond and A. C. Dennis.

Mr. Purdon. C. D. Purdon, M. Am. Soc. C. E. (by letter).—This question has been considered more or less by nearly all the Western roads, in the last few years, in connection with improvements of gradients.

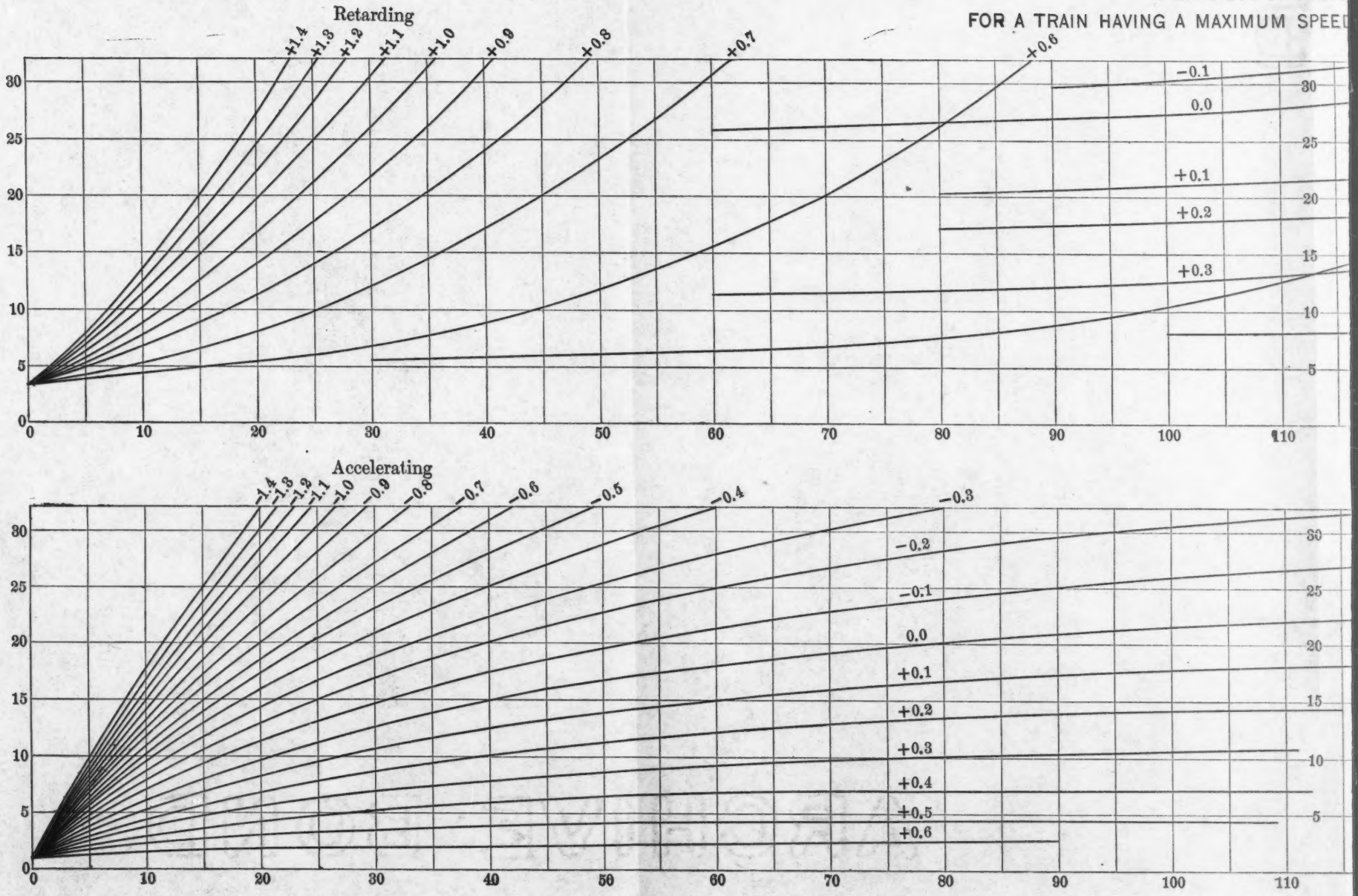
It is well known that the momentum of a train does assist in climbing adverse grades, and the only objection that the writer has heard made by engineers is that, in case of a train getting stalled at the foot of a grade, it would not be possible to start again with the maximum load; and for this reason some engineers advocate that in reducing grades they should always be reduced to the new maximum, regardless of their length. If this were done, however, the operating department would, no doubt, find out in a short time what maximum load could be operated over the reduced grades, and would undoubtedly use that load; so that it would seem advisable in grade reductions to take account of the momentum. This, however, the writer would only advocate in connection with the reduction of grades on an existing road.

In building a new road he would not exceed the maximum grade adopted in any case, as the principle of momentum afterward applied would simply make the new road so much the better, besides which, on a well-established road the stations have already been settled, and the stopping points for trains, at stations, water tanks, etc., have bee

* Continued from December, 1902, *Proceedings*. See November, 1902, *Proceedings*, or paper on this subject by A. C. Dennis, M. Am. Soc. C. E.

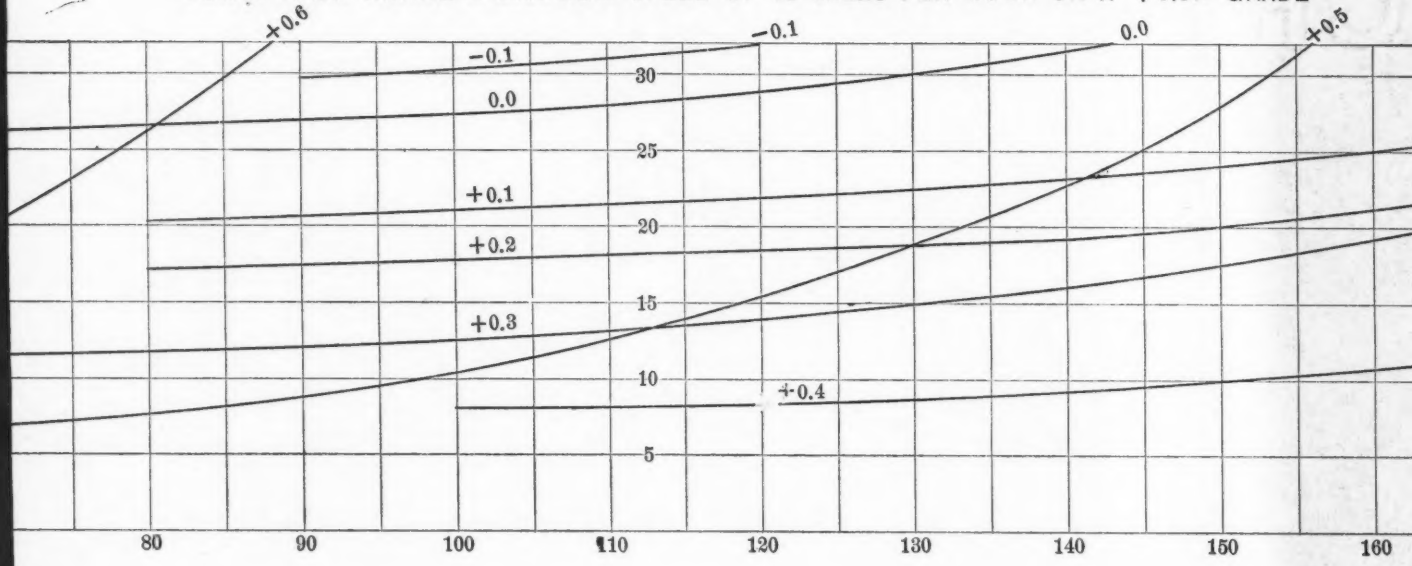
VELOCITY HEA

FOR A TRAIN HAVING A MAXIMUM SPEE



VELOCITY HEAD AND TRAIN SPEED

FOR A TRAIN HAVING A MAXIMUM SPEED OF 12 MILES PER HOUR ON A +0.5% GRADE



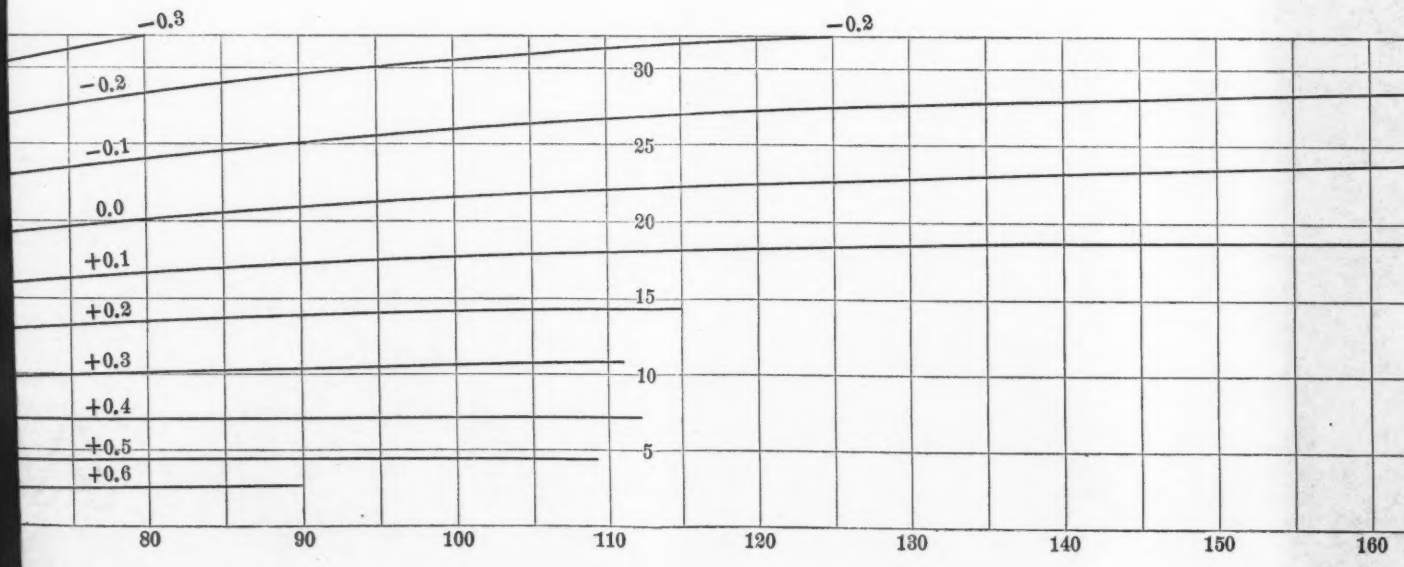
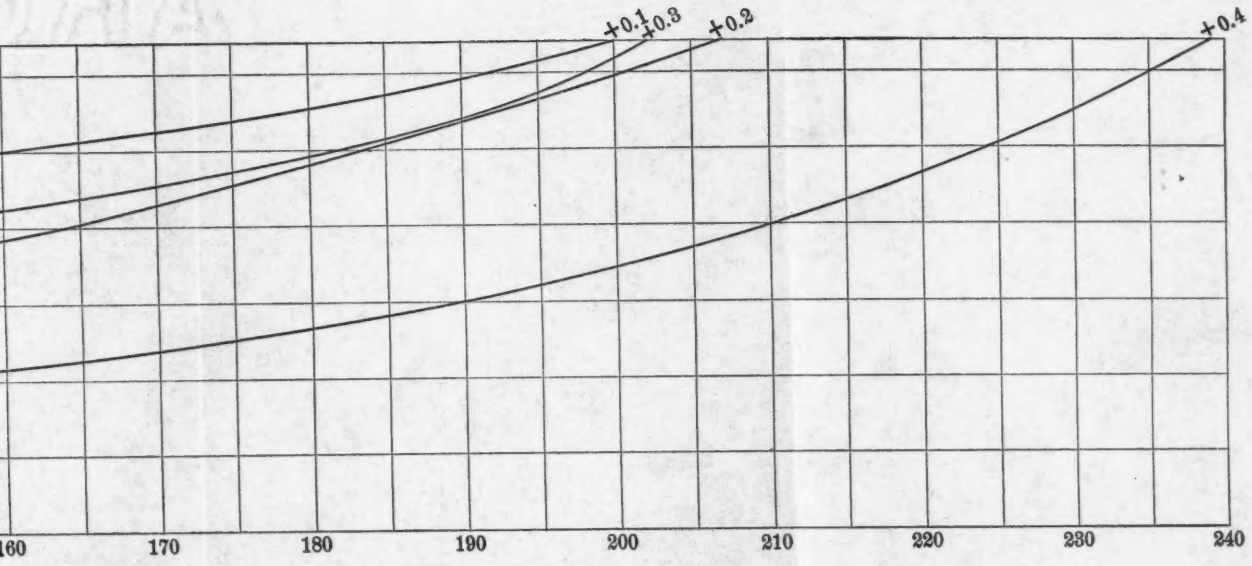
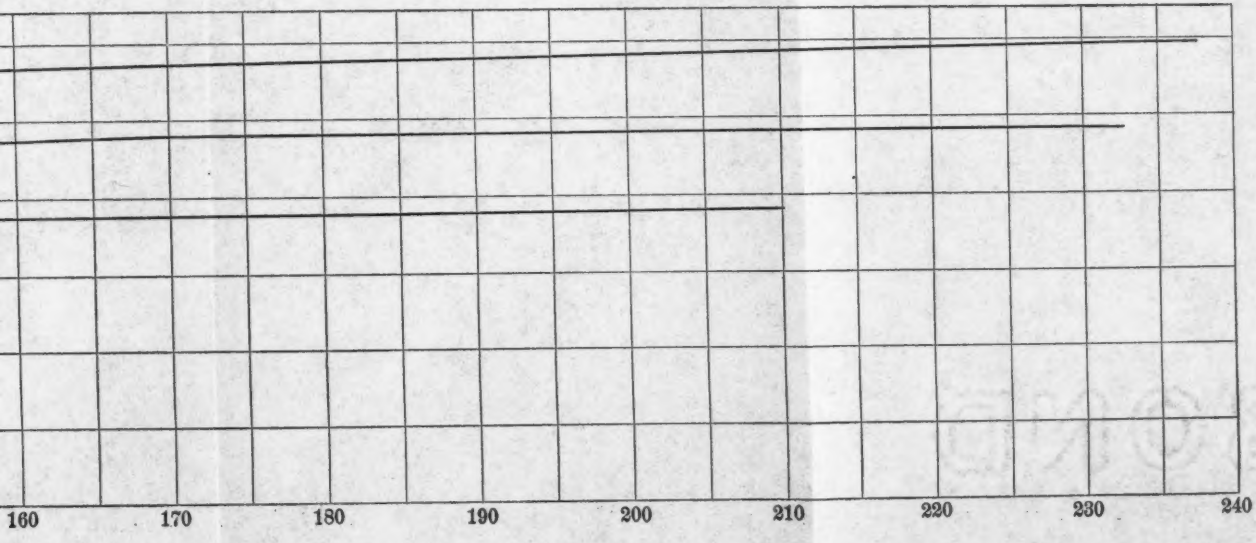


PLATE XIV.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
PURDON ON VIRTUAL GRADES.





established, so that the momentum can be calculated with considerable accuracy. On a new road, all these points will come up later, and if momentum grades were established on a new road, the introduction of a water tank or a new station, or some other reason, might destroy all calculations. Mr. Purdon.

The writer does not consider the author's diagrams as the most convenient for the purpose, and submits herewith two diagrams, Plate XIV, such as he uses. These take no account of the speed of the train, but use the velocity head, which, of course, is interchangeable with the speed. These particular diagrams are calculated for a train that can maintain a speed of 12 miles per hour on a rising grade of 0.5 per cent. The accelerating grades start with a velocity head of 0.88, equal to 5 miles per hour, and, after a stop at a station, the distance required to gain this velocity is taken as the starting point on the accelerating grade.

The upper diagram shows the retarding grades, and stops at 3.55, equal to a speed of 12 miles per hour, so that by taking any velocity head required by the upper diagram the distance on any adverse grade which would be run by a train before the speed would fall to 12 miles per hour can be ascertained. The diagrams are calculated in substantially the same manner as those by Mr. Dennis,* but in making the calculations the rating diagram of the Southern Pacific Railroad was used, which gives varying train resistance on account of speed from 4.8 lbs. per ton at ten miles per hour to 20½ lbs. per ton at 46 miles per hour. It is noticed that this does not agree with Mr. Dennis' paper, as he states that the train resistance is nearly the same for speeds between 7 and 35 miles per hour. At stations, of course, the grade should be somewhat lighter for a short distance on each side, to enable a train with a maximum load to start; and, in ascertaining the momentum, it should be calculated as if the train stopped at each station.

F. H. HEBBLETHWAITE, Assoc. M. Inst. C. E.—In the year 1900 the speaker was engaged at the Naval Yard Extension Works, in Hong Kong, in laying out a yard for the manufacture of concrete blocks. The concrete was machine-mixed at one end of the yard, run down grade on trestles in cars of 18-in. gauge, and dumped into moulds, the empty cars being pushed back by hand. A loaded car weighed 4 000 lbs., the empty car 500 lbs. Mr. Hebblethwaite.

The speaker would like to ask the author how he would determine the grade down which the loaded cars could be pushed with exactly the same expenditure of power as would be requisite to push the empty cars up; in fine, the grade to be laid out so that a man could as easily push an empty car up as a loaded car down. There must be such a grade. How can it be determined?

* In a paper published in *Engineering News*, November 22d, 1900.

Mr. Raymond.

WILLIAM G. RAYMOND, M. Am. Soc. C. E. (by letter).—The writer supposes that the late A. M. Wellington, M. Am. Soc. C. E., was the first railroad engineer to discuss at all adequately the problem of momentum or velocity grades, and, for a number of years after the appearance of his discussion, comparatively little attention was paid to the subject; but, for the past five or ten years, railroad engineers all over the country have been somewhat carefully studying and experimenting with such grades, and there have appeared in print, in the technical press and society proceedings, a very considerable number of discussions, both purely theoretical and as the result of extended experiments.

But while we engineers are figuring theoretically the gains to be secured by the consideration of momentum or velocity grades, and while the western roads have, in many instances, laid out such grades and operated them with apparent success and economy, we are met by the manager of the busy eastern road with the statement that on his road he does not dare to start out a train the engine of which is loaded with a load greater than that with which it can start from a state of rest on the steepest *de facto* grade over which it is to pass.

The writer himself, from time to time, has taken part in discussions of momentum grades, and has devised formulas for the lengths of such grades for given locomotives and resistances, and has discussed at some length the most economic speed of freight trains and the principles which should govern in the design of locomotives for operation on divisions of varying characteristics; and while he thoroughly believes that considerable economy may result from a consideration of momentum or velocity grades, in the cost of original construction, in the revision of gradients on existing roads, and in the designs of motive power and its operation; nevertheless, he can well understand that on a busy road the cost of a single unexpected stop, due to too close figuring on the possibility of momentum grades, may equal or exceed the gain resulting from such considerations for a considerable period of time during which there is no such accidental stop.

The writer believes that the subject is one of considerable importance because of the possible economies involved, and thinks that a fairly complete knowledge of the prevailing practice in this matter would be of very considerable value and interest, and, therefore, he suggests the advisability of securing the opinions of operating managers on this subject, and a statement of any experiences that such managers may have had in the consideration of momentum or velocity grades. He thinks that it might be wise to invite formally such expressions from officers responsible for the operation of both eastern and western railroads. These officers may include chiefs of motive power, general superintendents, general managers and chief engineers, according to the duties and responsibilities assigned to these different officers on the different roads.

A. C. DENNIS, M. Am. Soc. C. E. (by letter).—The writer fully agrees with the conclusions in the first part of Mr. Fulton's discussion on virtual grades, and was equally skeptical in regard to the approximate constancy of train resistance until convinced by a long series of experiments. He knows from experiment that a train of about 2 100 tons, with 20% empties, picked up speed from 29.5 to 30 miles per hour, with the locomotive shut off, in running 2.5 miles on a 0.26% grade. The writer suspects that a long train of all loads would exceed 40 miles per hour on a 0.3% grade with the locomotive shut off, provided the train had been running at high speed, but lacks sufficient information regarding resistances at such speed to be able to state definitely. A train of all empties will lose speed in coasting, even on a 0.4% grade, whatever the speed when starting to coast. It is impracticable to compare the resistance of two trains without knowing the proportion of tare weight, or reducing all actual tonnage to rating tonnage. Mr. Dennis.

The "boiler momentum," to which Mr. Randolph refers, will probably explain the difference between Mr. Fulton's speed and distance diagram and that of the writer.

The writer's locomotive tractive power curve for high speeds is much above the capacity of the locomotive to produce indefinitely, but not above that produced temporarily in making runs at grades. The available stored energy is roughly equivalent to 2 lbs. per ton of train or to 0.1% of grade.

If Mr. Fulton did not consider the extra temporary boiler power, but calculated his locomotive power as strictly limited by the steam-generating capacity, his diagram should show the same results, for any rate of grade, as the writer's does for the next tenth higher. Comparing Mr. Fulton's diagram with the next tenth higher corresponding grade on the writer's diagram shows a very gratifying correspondence until a mile is covered, or low speed reached, where the two diagrams are practically the same, as the boiler momentum has then ceased to influence the writer's diagram. As before noted, after passing the first mile, on a grade where the locomotive is worked hard at a speed exceeding ten miles per hour, the grade line on the writer's diagram does not hold, but the true results are approximated by following from this point parallel to the curve of the next tenth lower grade rate. The boiler momentum, though not capable of being calculated exactly, should be considered, and has been rather undervalued by the writer, as trains require more speed and hold it better when running for momentum grade than is indicated by the writer's diagram, except for long hills, where the diagram falls short, as noted.

The problem of momentum grades contains so many personal, mechanical, and other variables, that an approximate solution only is possible. A close approximation only is necessary, as trains are not

Mr. Dennis. loaded ordinarily to the last ton possible, because they cannot make the required time; so a little too much momentum grade introduced will not cause stalling, and if not as much as was possible were used, some returns are obtained, for the extra construction expense, in the running time saved.

The custom, on eastern railways, of sticking to an assumed maximum grade rate, regardless of cost, stations or speed possibilities, gives a line of higher first cost and generally of a lower operating value, because of the high ruling grade at stations. Momentum grades, based on the assumption that the locomotive exerts the same tractive power at all speeds, will lead to serious error. Somewhere between these extremes is the proper use of momentum, where the greatest liberty is taken with the grade rate to make it fit the ground, limited only by the ability to join with proper vertical curves and the capacity of the locomotive plus momentum to make the required speed. Engineers who look on the percentage of rate of grade as the end and object of a railway have mistaken the measure for the thir g itself. A grade should be limited, not to a maximum rate, but to the locomotive power, and the momentum then made to fit the ground. The mere rate of grade is irrelevant and often misleading.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

AN ALTERNATIVE LINE FOR THE NICARAGUA CANAL; AND A PROPOSED NEW METHOD OF DAM CONSTRUCTION.

Discussion.*

By J. Francis Le Baron, M. Am. Soc. C. E.

Mr. Le Baron.

J. Francis Le Baron, M. Am. Soc. C. E. (by letter).—The writer did not expect that the members of the Canal Commission would be swift to approve any change of route of the canal that they had already located after such careful examinations, but he recognizes fully the fact, illustrated so clearly by Mr. Noble, that the Isthmus is a country of surprises, and he felt that possibly a surprise might be in store on the south side of the San Juan, if a survey should be made there. Most of those who have taken part in the discussion have fallen into the error of supposing that the writer advocated this route as a finality, whereas he was careful to state in the paper that he believed the facts warranted a careful survey and examination, and that is as far as he felt warranted in going.

In replying to the discussion, the writer wishes first to mention the map, Plate XXXVIII.† As Mr. Noble surmised, the foundation of this map is the one published in the report of the Nicaragua Canal Commission, which is a reproduction, with additions and corrections, of the map published in the Lull Report of 1872–73. To the Commission's map the writer has added the topography developed by the special surveys and reconnoissances of the Nicaragua Canal Commission and

* Continued from December, 1902, *Proceedings*. See October, 1902, *Proceedings*, for paper on this subject by J. Francis Le Baron, M. Am. Soc. C. E.

† *Proceedings*, Am. Soc. C. E., for October, 1902.

Mr. Le Baron. the Nicaragua Canal Board, all of which are published in their respective reports, and, consequently, are official. There is no other topography on the map; therefore, if "only visible to the eye of faith," their correction is due from Mr. Noble and his associates and engineers.

The topography at the mouth of the Colorado is from the survey of Mr. P. C. F. West, Assistant, United States Coast Survey. The writer was very careful to make use of only actual surveys from official sources. In relation to this subject it may be stated that some of the maps of Nicaragua and Costa Rica show a cut-off, from the Serapiqui River direct to the sea, called the Sucio River. In case this cut-off exists, the whole volume of the Serapiqui, as well as that of the Tiger and Negro Creeks, could probably be turned through it and discharged ten or a dozen miles southeast of the canal, thus greatly simplifying matters. The writer did not allude to this in the paper, because the correctness of the maps had not been confirmed by actual survey, to his knowledge; but it emphasizes the desirability of a survey and examination on the southern side of the river.

The writer admits that the crossing of the Serapiqui is one of the most formidable engineering features of a line south of the river, but he does not believe it to be beyond the pale of engineering skill at the present day, in view of the experience on the Manchester Canal, and others. He examined the river for some distance above its mouth, and found it to be a deep-flowing stream, between steep banks, with a uniform and moderate velocity, carrying a dark-colored water, which shows that it runs through or drains large swamps, and is entirely unlike the San Carlos, which is very rapid and full of sandbars. In fact, the Serapiqui, in the lower part of its course, flows for a long distance through swamps and alluvial plains, whereas the San Carlos issues almost directly from the mountains. The upper courses of the two rivers are probably much alike. In its ordinary stages the Serapiqui is not a sand bearer in the lower part of its course, where it joins the San Juan. This is shown by there being no sand bank or bar at its mouth. The sand that it carries in its upper reaches is all deposited before reaching the San Juan.

The canal line would cross the Serapiqui within a mile of the mouth, and, by placing a movable needle-dam immediately below the crossing, the depth and velocity could be regulated at the time of passage of every vessel. Vessels would lock down or up on each side, as the case might be, which would be governed by the relative elevation of the water in the canal and river. At all events, the locks would be of low lift, not more than half the total rise of the river, or, say, a lift of 6 or 7 ft., and the canal would be taken into the river, not the river into the canal. When ships were passing, the needles in the dam would be closed, forming a slack-water pool of small extent. When

Mr. Le Baron.

the ship had passed and the needles were opened the water would quickly return to its former level, and the resulting scour would preserve the depth of the crossing, no weirs or spillways being necessary. The works required would be two low-lift locks and one needle-dam, with their accompanying guard gates, drift fenders and guide wings, the total cost of which might amount to $3 000 000, which would be paid for by 10 to 20 years of dredging at Greytown Harbor, taking the estimate of Mr. Noble; which dredging would be almost entirely eliminated by using the Colorado mouth. In other words, by an expenditure of $3 000 000 for crossing the Serapiqui, and by locating the harbor at the Colorado mouth and using the forces of Nature to scour out the harbor channel, there would be effected a saving of from $100 000 to $200 000, yearly, forever.

The writer thinks that the charts are at variance with General Hains, as to the Harbor at Colorado. This is a matter of fact, and not opinion. There are open harbors, and there are closed harbors. As shown in the paper, according to the surveys of the United States Coast Survey, a harbor of large extent now exists there for light-draft vessels. The writer has used it—crossing the bar in a vessel of 8 ft. draft. This harbor, as previously stated, consists of Agua Dulce Lagoon, Simon Lagoon and the Colorado River, here about 1 000 ft. wide. At present, for want of more water on the bar, this is a closed harbor to deep-draft vessels; but there is no reasonable doubt that it can be opened by two jetties, as has been done in so many similar places, and, possibly, by a single reversed jetty, on the well-known plans invented by a member of the Commission, and applied successfully elsewhere. Once opened, the current of the river, guided and controlled, will preserve an open channel. Greytown Harbor will require two jetties, and so will the Rio Indio, as admitted by the Canal Commission, and so will any harbor on this coast, Colorado excepted. The latter, possibly, can be built with only one jetty, on account of the strong current and great volume of the river; therefore the position of Professor Haupt is untenable, *viz.*, that the Colorado presents a less favorable condition than Greytown, as the expenditure for jetties would be about the same in both cases.

When making his studies and report on Greytown Harbor, for the Canal Company, the writer was very much surprised to find that the sand movement along the beach, northwest of the Greytown bight, was southeast, or directly into the bight. On the southeast side the movement was in the opposite direction, also into the bight. This was not a temporary drift, but prevailed during the continuance of the easterly winds. The writer's headquarters and residence were on the beach, so that the movement was a matter of daily observation. On account of this sand movement the writer planned the harbor with two converging jetties, placing the easterly jetty 900 ft. east of its present

Mr. Le Baron. position. It was afterward moved west for some reason, when constructed.

The Isthmian Canal Commission in its report admits* the possibility of two jetties being required at Greytown, and also at Rio Indio, which would each be as long, if not longer, than those required at Colorado bar, and with the additional disadvantage that from 500 000 to 1 000 000 cu. yds. of sand would have to be dredged annually to preserve a channel at Greytown, whereas, at the Colorado, it is probable that, with the channel once established, no dredging, or at least only a nominal quantity, would be required, for the reason that at the former place the current is weak and the outflow scanty, whereas at the latter there is a normal discharge of 62 000 cu. ft. per second, and at times nearly double this quantity, and a strong outflowing current to preserve a deep entrance, sufficient, even now, to maintain a channel depth of 30 ft. in the gorge, as is shown by the Coast Survey chart before referred to.

The problem of a canal harbor on the eastern end, then, seems to resolve itself to this: A harbor can be built at Greytown, in the location selected by the Commission, which is a small bight in the coast line, into which is annually being poured from 500 000 to 1 000 000 cu. yds. of sand, as estimated by Messrs. Noble, Haupt and the late Professor Mitchell. This sand movement at this locality has been going on for long geological ages. This is shown unmistakably by the remarkable series of lagoons, some half dozen in number, which have formed back of Greytown at regular intervals, beginning with Silico Lagoon and ending with Greytown Lagoon. The last two—Shephards and Greytown—have been formed in the present or historic age, the latter being completed in 1865, and the former about 200 years before, according to tradition in the locality, which, for confirmation, points to the remains of the old caraval belonging to that redoubtable pirate Shephard, who, in the days of the freebooters, made this lagoon his rendezvous, and from whom it was named. Here he retired after his forays, and, on the last occasion, a storm closed the outlet and the vessel was never able to escape. There it remains to this day, a grim and silent warning of what might happen in the year of grace 2100, in case our dredges should break down or the groynes fail to stop the course of Nature.

It is admitted that a harbor can be built in the place selected at Greytown; but, is it wise to select a point where six harbors have previously been built and filled up? Nothing is impossible in these days of engineering, if plenty of money is furnished. It is admitted that it can probably be kept open for many years by building groynes and by constant dredging, but the groynes must be extended every few years, and the dredging must never stop.

* Report of the Isthmian Canal Commission, p. 141.

Mr. Le Baron.

The open book of Nature shows conclusively that here the lagoon-building process is still going on, and sand is being brought in from the north and the south. Year after year the sand that will be dredged from the harbor will accumulate around it; the foreshore will keep on increasing and building out, until at last the advancing mole, as was the case with the last harbor, pushes its irresistible way across the floor of the ocean and closes the harbor, and another lagoon is formed, as has been formed six times before. The delta here has been for ages and is still actively building out into the sea. When Greytown Lagoon was formed, this sand mole, advancing from the southeast up the coast, crossed the harbor in 48 ft. of water, and in 15 years completely shut up the once fine port. By building a harbor in the same spot we are inviting the same disaster.

On the other hand, we have the mouth of the Colorado River, a mighty stream, 30 ft. in depth, rolling seaward between banks 1 000 ft. apart, and yearly growing larger on account of the gradual diminution of volume of the Greytown branch, the Lower San Juan. Once inside the bar, here is a harbor capable of accommodating many vessels, as stated in the paper. If this is not a harbor, as General Hains claims, then the Mississippi River from Port Eads to New Orleans is not a harbor. True, the sea breaks on the bar, as General Hains observed; but on what bar does it not break when it has a long reach of deep blue water behind it. The writer, sitting in his office on the beach at Greytown, has seen the spray thrown 20 ft. high, day after day, from the breakers at the site of the Commission's proposed harbor. Breakers in any place certainly do not present very stable equilibrium to a man in a boat; but the fact of their existence being taken to militate against a condition of stable equilibrium of the coastal plain, as General Hains, facetiously, perhaps, infers, is certainly a new postulate in hydrography.

Professor Haupt concludes, from his studies of Greytown Harbor, that "the problem of restoring it is quite practicable and comparatively inexpensive." The datum on which this opinion is based appears to be the fact that a quantity of sand, estimated by himself at 582 000 cu. yds., and by the late Professor Mitchell at 730 000 cu. yds., and which Mr. Noble says may be anywhere from 500 000 to 1 000 000 cu. yds., is annually deposited in the bight where it is proposed to form the harbor; that the advance of the sand mole up the coast was at the rate of 291 ft. per annum, and that from 29 to 31 years, only, would be required to fill or close it. Moreover, he characterizes this movement as "due to the constancy of the prevailing forces"—certainly rather unusual recommendations for a harbor site.

It is true that Professor Mitchell (about 1869) reported that the harbor could be restored. At that time there existed a good, deep

Mr. Le Baron. basin, fully 30 ft. deep, and more in some places; now, the basin will not average 18 ft. deep, and is not more than half the area it was then. At that time the harbor was worth experimenting with; now, it is not. It is not claimed that it cannot be restored now, but it is submitted that it would be unwise to expend any money on it when there exist other locations free from the deteriorating influences that prevail here. It is sure to fill up at the first opportunity, no matter how carefully it is protected by groynes or pumped out by dredges.

The Isthmian Canal Commission, in its report (page 162), states that "the sand movement along the coast seems to be at the maximum at Greytown." It would be interesting to know by what line of reasoning it arrived at a favorable decision to locate a harbor at a point possessing all these disadvantages, and no apparent advantage, except that in its opinion it has "advantages as a working harbor." The writer is forced to agree fully with the Commission in the latter view, considering the amount of sand it estimates must be removed yearly.

The region included between the Colorado and Greytown is a delta, and it is known that deltas are invariably progressive, but, as Professor Haupt very wisely concludes, the movement is cyclic in character in portions of this delta, and this accounts for the erosion at present in the vicinity of the mouth of the Rio Tamo; as Mr. Noble observes, "the action now going on being a straightening of the shore line."

Professor Haupt quotes the writer as saying that "the conditions at the mouth of the Colorado present a nearly stable equilibrium," and that "the whole littoral, from the highlands at the mouth of the Colorado to the present canal mouth, is in a condition of constant accretion," and considers these statements as contradictory. The writer fails to see any contradiction therein, as he states plainly that the accretions commence at the Colorado, where they are zero, and extend to Greytown, where they are known and admitted to be immense.

Now, a word as to littoral currents: These currents, as shown on navigation charts, are apt to be misleading to the engineer, and their value to him, as part of the problem of harbor or bar improvement, depends upon their distance from shore. Where there exists a strong littoral current, a mile or two off shore, running in a certain direction, there is almost sure to be a surf race in the opposite direction, as is the case on the Florida east coast,* the coast of Honduras and at other places, which have come under the writer's personal observation. This is the case here. These contrary currents are in the nature of an eddy, and partially restore the equilibrium of the water. This accounts, also, for the current running in the face of the trade winds, which puzzles Mr. Noble. The writer has often observed this on flat,

* *Transactions*, Am. Soc. C. E., Vol. xliii, p. 95.

sandy coasts. It is only in this way that the equilibrium of the sea can be restored. Wherever the sand comes from, it is certain that at Greytown it is continually traveling northwest into the bight of the coast line. This movement was reported by the English engineers, Passamore and Climie, who made a survey of Greytown Harbor for the Nicaraguan Government in 1874, and whose report was published in Spanish by that Government. This survey was made to devise a plan for restoring the Harbor of Greytown, and in it they advocate deepening and jettying the mouth of the lower San Juan River, cutting off the flow from the Harbor of Greytown, which was to be entered from the river by a tide-lock, they arguing that the increased volume and velocity of the outflowing current would form a "breakwater of water" (*rompolas de agua*), which would arrest this sand drift and thus preserve an open entrance for the harbor to the westward. Just how this would be accomplished was not made clear. Mr. Le Baron.

In regard to the alignment south of the San Juan, Mr. Noble considers that "it is not likely that it would be materially better than that now obtained on the left bank," and states that "the divide is about 50 miles distant." Just what is meant by the "divide" is not quite clear, but it is immaterial. The important matter is the width of the intervale or river bottoms, and this is known to be wider on the south side.

It is known that Colonel Childs supposed that the high hill on the south side of the San Juan and east of the mouth of the Serapiqui was a spur from the Costa Rican Mountains, and he based his project of canalization of the San Juan River on this supposition.

Later reconnoissances proved this to be an isolated hill, with a large and unknown extent of swamp behind it, thus making it impossible to canalize the San Juan by means of a high dam at this point, as proposed by Colonel Childs. Still later, it was hoped, during the several surveys made by the Nicaragua Canal Company, and by the United States, that spurs suitable for this purpose could be found opposite San Francisco Island or Tamborcito and other places, and various examinations were made of the south side for the purpose of discovering such spurs; but all proved futile. These various surveys have demonstrated that the river bottoms on the south side extend many miles south of the river, being dotted with only occasional isolated hills, whereas on the north side, as first stated, the mountain spurs of the Cordilleras come abruptly down to the river in numerous places, and have to be cut through by any line on that side. These facts support the writer's contention that on the south side a very much better alignment can be found than exists on the north side, and the engineer is justified in being more sanguine of finding "captivating tangents" when all the facts demonstrate that the ground for them exists. The experience of large ships in the curves of the Suez Canal shows conclusively the importance of these "captivating tangents,"

Mr. Le Baron. even at the expense of more costly works at the crossing of the Serapiqui. The writer repeats, enough is known of the topography of the south side to justify the belief that the alignment can be bettered nearly 75% on that side; and, while the line, as laid down on the writer's map, may very likely have to be shifted in places, the surveys already made show that no material change need be expected or looked for, as this line is laid down in accordance with known and accurately delineated topography.

The comparison made by General Hains between the anchor chains of a light-ship and the net chains enclosing the rock-filled dam is not appropriate. The anchor chains of a ship are continually in motion, being dragged about on the ocean floor while the ship is tugging and straining at her anchor, whereas the chains enveloping the rock-filled dam will lie almost quiescent, being held firmly in place by the rough rocks composing the dam itself, and, in turn, holding those rocks. Where the ship's chain is continually grinding up the sand between each link and thus always abrading every wearing surface, the net chains will lie quietly in the dam, covered by the rough stones, and only exposed to the abrading action of such sand as is brought against it at a few exposed points, and it will occur to anyone that this chain net can be carried clear across the dam, during the process of construction, every 10, 20 or 30 ft. in height, if desired, and so connected by split links, up and down and right and left, as to form in reality a number of nets all connected together, so that if it should be worn away at one place it will be held in another a few feet distant, perfectly protected by the enclosed and superincumbent rock. This also answers the next question as to how loose stone will be held on the down-stream slope during a great flood. In other words, there will not be a single net or bag, but a series of nets, one above the other, and all linked together. Neither will it be necessary, as will occur to any practical engineer, to draw the chain up against the stream, but it can be drawn down with the current, and thus spread over the rock.

The rusting of iron or steel under water in the course of ages is, of course, admitted, but in fresh water this is a comparatively slow process. If, for this reason, engineers are to be deterred from using it, three-fourths of the engineering constructions of the present day, such as steel caissons for bridges, piers, etc., must be condemned. A little reflection will show that when these cables are rusted out, a new chain net can very easily be spread over the dam, which, by that time, however, will have become consolidated and stable, except possibly on the crest.

The Conchuda Dam is to be of masonry, and General Hains says this is "perfectly safe and practicable." This cannot be said truthfully of any masonry construction in an earthquake country. As General Hains says, somewhat sarcastically, "a rock-fill dam is the

only dam known that is improved by earthquakes," and quotes the writer as saying that "an earthquake would only serve to consolidate it and fill up the voids." The writer repeats that this is his opinion, but he does not claim credit for its originality. This feature of a rock-fill dam at Ochoa was advanced as a favorable one by the consulting engineers who reported on it several years ago. To trust the fate of the canal to a masonry dam, anywhere on the Isthmus, would, in the writer's opinion, be taking chances that no prudent engineer would care to take if they could possibly be avoided. The comparison of the wearing effect of sand in the bends of a centrifugal pump, having a velocity of 15 to 20 ft. per second in a closed tube, with that of a river current having a velocity of 4 to 8 ft. per second seems rather far fetched. Such terrible abrasion General Hains fears would wear away the crest of his masonry spillways in a short time. The amount of sand abrasion of a wrought-iron rod set in a smooth ledge close to a sand beach, in salt water, at the mouth of a tidal river where the tide-rip, heavily charged with sand, swept over the ledge with a velocity of 2 to 8 ft. per second, was at the rate of 1 in. in twenty years, as observed by the writer. In fresh water it would be less, and it may be safely placed at 1 in. in twenty-five years. Mr. Le Baron.

As a matter of fact, because a rock-fill dam is built at Ochoa, it does not follow that it must be built as a weir. The writer believes, as he stated in the paper, that a dam constructed as proposed would be perfectly safe as a weir, but it is not obligatory to build it as a weir. The dam can be built there, as at Conchudo, above the highest floods, and all the discharge of the river taken over the San Carlos spillways.

The location of a rock-fill dam at Ochoa has been favorably passed upon by two Boards of Consulting Engineers, and, with some modifications, accepted by the United States Canal Board, the first consisting of the Canal Company's engineers, Commander A. G. Menocal, Civil Engineer, United States Navy, Chief Engineer; Lieutenant (now Commander) R. E. Peary, Civil Engineer, United States Navy, Sub-Chief Engineer; the late E. P. Davis, Assistant Engineer, and the writer, at that time Principal Assistant Engineer. At that time more than eight months had been spent in studying the conditions on the ground.

The second Board consisted of well-known engineers, of high standing, not connected with the Canal Company. Of this Board, the late A. M. Wellington, M. Am. Soc. C. E., was Chairman.

The fact that a rock foundation is not known to exist in the San Carlos Ridge, only emphasizes the writer's contention that the south side of the river should be carefully examined and the line surveyed before construction is commenced, in order to compare properly the relative merits of the two plans, which was the only object of the paper; the facts, as the writer believes and so stated, warranting a survey of a route on the south side.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final Publication.

HENRY LAWRENCE CLEVERDON, Assoc. M. Am. Soc. C. E.*

DIED AUGUST 27th, 1902.

Henry Lawrence Cleverdon, known to the members of his family and to his most intimate friends as "Lonnie," was born at Washington, D. C., on April 6th, 1869. At the age of fifteen his parents returned to their former home, Chagrin Falls, Ohio, 18 miles southeast of Cleveland, and here he completed his common school education, and was graduated from the high school in 1888.

Being naturally an energetic boy, with an extremely practical turn of mind, and having decided early upon his life's work, he utilized his vacations, while still in the high school, as best he could to advance himself in his chosen profession. During the summer of 1887 he worked as Chainman for Mr. J. F. Brown, a Cleveland surveyor, and from April, 1888, until September, 1889, as Rodman on the Lake Shore and Michigan Southern Railway. While engaged on the latter work he came to realize the importance and value of a better education, and resigned to enter the University of Michigan as a student in the Engineering Department.

College work was always hard work with him—the means to an end—and, although he mastered his various studies with credit to himself, he chafed under too much confinement and longed for active outdoor life.

From July, 1890, to January, 1891, he served as Instrumentman and Resident Engineer on the construction of the Akron and Chicago Junction Railway (Ohio), now the Baltimore and Ohio Railway, and returned to college as soon as the work was finished. During the construction of the Wilkes Barre and Eastern Railway, through the mountains of Eastern Pennsylvania, Mr. Cleverdon was employed as Locating or Resident Engineer, from the beginning to the completion of the work, and some of the most difficult construction was under his direct charge. He expected to return to college and be graduated with his class—the class of '93—but one job after another came and was completed in such rapid succession that there seemed to be no time for anything else, and at last he gave up all thoughts of trying to return.

He served as Rodman on topographical surveys for the Short Line

* Memoir prepared by George H. Fenkell, Assoc. M. Am. Soc. C. E.

Improvement Company (Pennsylvania) from January to June, 1894, and from August, 1894, until April, 1895, was Resident Engineer, in charge of construction of six miles of the Fort Plain and Richfield Springs Railway (New York); but when the latter road was nearly ready for the track work was suspended, and Mr. Cleverdon, together with the other members of the engineering corps, was defrauded out of several months' salary, an incident that made him much wiser, if somewhat poorer. That he was not afraid of hard work, is shown by his serving first as laborer and then as Foreman and Superintendent for a water-works contractor at Fort Plain, New York, during the summer of 1895. During the autumn and winter of 1895–6 he was employed as an engineer on street railways and suburban electric lines in and near Cleveland, Ohio, and was Engineer in charge of the construction of three miles of a brick-paved highway for the County of Cuyahoga, Ohio.

From September, 1896, to October, 1897, Mr. Cleverdon was Resident Engineer in charge of construction of six miles of the Lorain and Cleveland Electric Railway, one of the first electric roads in the Middle States to be constructed in accordance with the best steam-road practice. In June, 1898, he was Locating Engineer for the Rapid Railroad, on a proposed line from Detroit to the St. Clair Flats, Michigan; and from August to November, 1898, Assistant Engineer on the Chicago and West Michigan Railroad, principally in charge of masonry construction.

He began work as Resident Engineer on the Cleveland and Eastern Railroad in January, 1899, but resigned in March, 1899, and in April began work as Division Engineer in charge of construction on the Copper Range Railroad, in Northern Michigan. This work was finished in June, 1900, and he at once accepted the position of Chief Engineer of the St. Johns and St. Louis Electric Railroad, Michigan, under the direction of the Arnold Electric Power Station Company, of Chicago, and remained there until the road was completed, in February, 1902.

For the next three months he was Resident Engineer on the Cleveland Water-Works Tunnel, and resigned this position to become Deputy County Surveyor of Cuyahoga County, Ohio, in charge of all bridges in that county.

On June 16th, 1902, he was married to Miss Elsie L. Williams, of Glenville, Ohio, and they at once began housekeeping in their new home, on the shore of Lake Erie, about 14 miles west of Cleveland. It then seemed as if his happiness was complete—a home, a loving wife, and a permanent position were appreciated all the more after fifteen years of the most active kind of work.

On the morning of August 23d, 1902, he boarded a car going toward Cleveland and requested the conductor to let him off at a farm road crossing about two miles farther east, to enable him to inspect a county

bridge located near the car line. For some reason not known, the car passed by the cross-road and finally came to a stop on a wooden trestle 50 ft. high, a trestle that Mr. Cleverdon had constructed in 1897 while Engineer in charge of the construction of this road—the Lorain and Cleveland. When the car stopped he swung off on to the trestle and began to walk away from the rear end of the car. The car started, but he supposed it had resumed its journey and gave it no further attention. As a matter of fact, the car was backing up, and the first warning he had of the impending danger was when it struck him. He partly jumped and was partly knocked from the trestle, struck a cross-timber on his descent and then dropped to the ground. When picked up a few moments later, in a semi-conscious condition, both limbs were found to be broken between the knees and hips.

He was taken to St. John's Hospital in the same car that struck him, an operation performed, his wife and family summoned and everything possible done to allay his sufferings and improve his condition. He did not seem to rally, however, and on August 27th, 1902, ten weeks after his wedding day, he passed away. The funeral was held the next day at his old home, Chagrin Falls, Ohio.

Mr. Cleverdon was a noble-hearted man, true to his friends and beloved by them in return. Always active and energetic, he had a wide circle of friends, scattered from one end of the country to the other, who mourn his untimely death.

He is survived by his wife, by his parents, one sister and four brothers.

Mr. Cleverdon was elected an Associate Member of the American Society of Civil Engineers on March 1st, 1899.

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NEW YORK 1903.

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American Society of Civil Engineers.

OFFICERS FOR 1903.

President, ALFRED NOBLE.

Vice-Presidents.

Term expires January, 1904:	*Term expires January, 1905:*
CHARLES C. SCHNEIDER,	L. F. G. BOUSCAREN.
JOHN R. FREEMAN.	JAMES D. SCHUYLER.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1904:	*Term expires January, 1905:*	*Term expires January, 1906:*
JOSIAH A. BRIGGS,	RICHARD S. BUCK,	ALFRED CRAVEN,
GEORGE F. SWAIN,	GEORGE H. PEGRAM.	JOSEPH O. OSGOOD,
EMIL KUICHLING,	WILLIAM J. WILGUS,	GEORGE S. DAVISON,
MORDECAI T. ENDICOTT,	WILLIAM JACKSON.	E. C. LEWIS,
EDWARD C. CARTER,	EDMUND F. VAN HOESEN,	HUNTER McDONALD.
FRANK C. OSBORN.	JAMES L. FRAZIER.	ELWOOD MEAD.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOSIAH A. BRIGGS,	GEORGE H. PEGRAM,	CHARLES C. SCHNEIDER,
L. F. G. BOUSCAREN,	ALFRED CRAVEN,	MORDECAI T. ENDICOTT,
GEORGE F. SWAIN,	JOSEPH O. OSGOOD,	EMIL KUICHLING,
RICHARD S. BUCK,	FRANK C. OSBORN,	WILLIAM JACKSON,
WILLIAM J. WILGUS.	GEORGE S. DAVISON.	CHARLES WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

ON RAIL SECTIONS:—G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 533 Columbus.
CABLE ADDRESS, - - - - "Ceas, New York."

Vol. XXIX. FEBRUARY, 1903. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

FIFTIETH ANNUAL MEETING.*

January 21st, 1903.—The meeting was called to order at 10.45 A. M., Vice-President Charles C. Schneider in the chair; Charles Warren Hunt, Secretary.

The reading of the minutes of the meeting of January 7th, 1903, was dispensed with.

Messrs. G. S. Stoddart and C. D. Pollock were appointed tellers to canvass the Ballot for Officers for the ensuing year.

The Annual Report of the Board of Direction† and the Annual Reports of the Secretary† and of the Treasurer† for the year ending

* A full report of the Fiftieth Annual Meeting is printed on pages 42 to 80 of this number of *Proceedings*.

† The Annual Reports of the Board of Direction, the Secretary and the Treasurer may be found on pages 5 to 14 of the *Proceedings* for January, 1903 (vol. xxix).

December 31st, 1902, were presented, and, on motion, duly seconded, accepted.

The Progress Report of the Special Committee on Uniform Tests of Cement* was presented by George S. Webster, M. Am. Soc. C. E., Chairman of that Committee.

At 11.20 A. M. the chair was taken by President Robert Moore.

On motion, duly seconded, the report was received and ordered printed in *Proceedings*, and the Committee continued.

On motion, duly seconded, the Committee was thanked for its labor and report.

A progress report from the Special Committee on Rail Sections was presented by L. F. G. Bouscaren, M. Am. Soc. C. E., Chairman of that Committee.

On motion, duly seconded, the Committee was continued.

The following were appointed members of the Nominating Committee for two years:

GEORGE W. TILLSON	Representing	District	No.	1.
J. P. SNOW	"	"	"	2.
EDWARD A. BOND	"	"	"	3.
RICHARD KHUEN, Jr	"	"	"	4.
L. E. CHAPIN	"	"	"	5.
JOHN B. ATKINSON	"	"	"	6.
D. C. HENNY	"	"	"	7.

The Secretary reported that the Board of Direction had awarded the prizes for the year ending with the month of July, 1902, as follows:

The Norman Medal to Paper No. 911, entitled, "Experiments at Detroit, Mich., on the Effect of Curvature upon the Flow of Water in Pipes," by Gardner S. Williams, M. Am. Soc. C. E.; Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 910, entitled, "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government," by William W. Harts, M. Am. Soc. C. E.

The consideration of the following proposed amendment to the Constitution was then taken up:

Amend Article III of the Constitution as follows:

Section 2, first line, after the words "Society as" strike out the words "Member or as Associate" and insert the words "a Corporate"; second line, after the word "to" strike out the words "either grade of."

Section 2, Art. III, will then read, "An application for admission to the Society as a Corporate Member, or for transfer from any other

* This report is printed in *Proceedings* for January, 1903.

grade to Corporate Membership shall embody," the rest of the section standing as now.

Section 3, third line, after the word "membership" strike out the words "in any grade," and after the word "transfer" strike out the words "from one grade to another"; twelfth line, for the word "may" substitute the word "shall." The section will then read as follows:

"At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for membership or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of the references in the case of Corporate Member, and endorsers in the case of Associate, Junior or Fellow, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on applications for Corporate Membership may direct a ballot."

This amendment was proposed by Messrs. H. G. Prout, G. S. Williams, Alf. P. Boller, Geo. Y. Wisner and Geo. F. Swain, and was sent to all Corporate Members on October 2d, 1902.

The amendment was discussed, but was not amended.

A resolution,* relative to the death of Abram S. Hewitt, was offered by George S. Morison, Past-President, Am. Soc. C. E., seconded by Robert W. Hunt, M. Am. Soc. C. E., and carried unanimously.

J. A. Ockerson, M. Am. Soc. C. E., offered the following resolution:

Resolved, That it is the sense of this meeting that the American Society of Civil Engineers should co-operate with the officers of the Louisiana Purchase Exposition Company, in the inauguration of an International Congress of Engineering, to be held in St. Louis, during the Exposition period of 1904, and be it further

Resolved, That the Board of Direction be, and is, hereby, authorized and requested to take such steps as may be necessary to carry out the provisions of the foregoing resolution.

The resolution, being duly seconded, was carried.

The Secretary presented the report† of the tellers appointed to canvass the Ballot for Officers for the ensuing year.

The President announced the election of the following officers:

President, to serve one year:

ALFRED NOBLE, New York City.

Vice-Presidents, to serve two years:

L. F. G. BOUSCAREN, Cincinnati, Ohio.
JAMES D. SCHUYLER, Los Angeles, Cal.

* See page 70.
† See page 72.

Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

Directors, to serve three years:

District No. 1.—ALFRED CRAVEN, Yonkers, N. Y.
District No. 1.—JOSEPH O. OSGOOD, Plainfield, N. J.
District No. 4.—GEORGE S. DAVISON, Pittsburg, Pa.
District No. 6.—E. C. LEWIS, Nashville, Tenn.
District No. 6.—HUNTER MCDONALD, Nashville, Tenn.
District No. 7.—ELWOOD MEAD, Cheyenne, Wyo.

Mr. Morison and Mr. Croes conducted Mr. Noble, the President-elect, to the chair.

The Secretary read a letter from Robert Moore, Past-President, Am. Soc. C. E., to the effect that, in pursuance of the resolution passed at the last Annual Convention an oak tree had been planted at Mt. Vernon as a memorial of the visit of the Society in May, 1902; and that this work had been executed by Messrs. Gifford Pinchot and George B. Sudworth, of the Bureau of Forestry, and Harrison H. Dodge, Superintendent of the Mt. Vernon Estate.

It was moved, duly seconded and carried that the Secretary be instructed by this meeting to extend the thanks of the Society to the gentlemen named for executing this commission.

Adjourned.

February 4th, 1903.—The meeting was called to order at 8.50 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 100 members and 20 guests.

The minutes of the meeting of January 7th, 1903, were approved as printed in *Proceedings* for January, 1903. The approval of the minutes of the Annual Meeting was deferred until they are printed in the *Proceedings* for February, 1903.

An informal discussion on "The Preservation of Materials of Construction," was opened by William Barclay Parsons, M. Am. Soc. C. E., who exhibited perfectly preserved specimens of wood taken from the excavation for the Metropolitan Underground Railway of Paris at the site of the ancient "Porte du Temple," founded during the reign of Charles V, 1364–1380. He also showed a section of wooden water pipe, taken from the excavation for the New York Rapid Transit Subway on Center Street, which had been in the ground about 100 years, and yet was perfectly preserved. The Secretary presented a letter from Mr. James Forgie, Chief Assistant Engineer of the City and South London Deep Underground Railways, transmitting and describing a piece of iron about 200 years old, in the form of a masonry

cramp or bonding iron, on which no trace of rusting could be seen. The iron had been found, in 1899, embedded in the sandstone masonry of a pier in the crypt of St. Mary Woolnoth Church, in London, where the foundations of a railroad depot were being made. The letter was accompanied by a photograph of the crypt, showing the place where the iron was found. Rudolph P. Miller, Assoc. M. Am. Soc. C. E., described the condition of the metal in a large building of modern construction, in New York City, which is now being taken down, and illustrated his remarks with lantern slides.

The subject was discussed further by Messrs. George Hill, W. W. Kenley, George A. Just, Edward P. North, Oscar Lowinson and Henry B. Seaman.

Ballots for membership were canvassed, and the following candidates were elected:

As Members.

Harry Sherman Bosler, Akron, Ala.
George Elvin Datesman, Philadelphia, Pa.
Arthur James Dyer, Nashville, Tenn.
William Henry Finley, Winnetka, Ill.
Graham Denby Fitch, Little Rock, Ark.
Isham Randolph, Chicago, Ill.
Charles Winslow Sherman, Boston, Mass.
Henry Clark Thompson, New York City.
George Monroe Wisner, Chicago, Ill.

As Associate Members.

James Marcus Bandy, Greensboro, N. C.
Edward Christian Henry Bantel, Austin, Tex.
Sam Wigfall Bradshaw, Steelton, Pa.
Per Brynn, Pittsburg, Pa.
Harris De Haven Connick, San Francisco, Cal.
Richard Turner Dana, Ridgewood, N. J.
Edward Bliss Day, St. Louis, Mo.
Horace De Remer Haight, Albany, N. Y.
Joseph Milton Howe, Houston, Tex.
Henry Scudder Jaudon, Birmingham, Ala.
George Albert McKay, Newport, R. I.
Hibbard Atwill Paine, Chandler, Okla. T.
William Edwin Pincombe, Calcutta, India.
James Vincent Rockwell, Eagle Grove, Iowa.
Edward Moses Stayton, Hope, Ark.
Lazarus White, New York City.

The Secretary announced the election of the following candidates by the Board of Direction on February 3d, 1903:

As Associates.

Rudolf Caspar Carl Marie Bernegau, New York City.
Otto Balthazar Keller, New York City.
Eugene McGrath Quirk, Montreal, Que., Canada.

As Juniors.

John Seager Adey, New York City.
Robert Jay Bassett, Steelton, Pa.
John Anthony Crook, Falls City, Neb.
Shukichi Fujino, Pencoyd, Pa.
Hugh Melvin George, Meridian, Miss.
Frederick Appel Hausman, Bridgeport, Pa.
Vernet Albert Kauffman, Alamogordo, N. Mex.
Henry Jacob Kolb, Steelton, Pa.
George Edson Philip Smith, Tucson, Ariz.
Travis Logan Smith, Jr., Fulshear, Tex.
Charles Underhill Stepath, New York City.
Carl Tombo, New York City.
Edward Lloyd Walker, Paterson, N. J.
Ezra Bailey Whitman, New York City.
Waldo Gilman Wildes, Clinton, Mass.
Benjamin Lee Williams, Jr., West Orange, N. J.
Carolus Hermann Zane-Cetti, Fort Worth, Tex.

The Secretary announced the death of the following members:

Watson Wellman Rich, elected Member September 5th, 1883; died January 12th, 1903.

Estevan Antonio Fuertes, elected Member February 17th, 1869; died January 16th, 1903.

Elnathan Sweet, elected Member November 6th, 1878; died January 27th, 1903.

Adjourned.

February 18th, 1903.—The meeting was called to order at 8.50 p. m., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 121 members and 35 guests.

A paper entitled, "The Panama Canal," by George S. Morison, Past-President, Am. Soc. C. E., was presented by the author, and illustrated with lantern slides.

A written communication on the subject, by M. Meigs, M. Am. Soc. C. E., was presented by the Secretary.

The subject was discussed orally by Messrs. Theodore Paschke, W.

H. Burr, C. L. Harrison, Boyd Ehle, W. E. Crane, P. Bunau-Varilla and the author.

The Secretary announced the death of JOHN WALKER BARRIGER, Jr., elected Junior May 31st, 1898; Associate Member, April 2d, 1902; died December 19th, 1902.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 21st, 1903.—2.30 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Buck, Craven, Davison, Jackson, Knap, Moore, Osgood, Pegram, Schneider, Swain and Wilgus.

A Committee on Finance, a Library Committee, a Committee on Publications, and a Committee on Membership, were appointed.

A letter-ballot was ordered for the election of a Secretary for the ensuing year.

Adjourned.

February 3d, 1903.—8.40 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Craven, Croes, Endicott, Knap, Kuichling, Osgood, Swain and Wilgus.

The ballot for Secretary was canvassed, by tellers appointed for the purpose, and Chas. Warren Hunt was declared elected.

The resolution, passed at the Annual Meeting, recommending co-operation with the officers of the Louisiana Purchase Exposition Company, in the matter of a proposed International Congress of Engineering, to be held in St. Louis during the Exposition of 1904, was referred to a Special Committee of the Board.

The resignations of Horace See, M. Am. Soc. C. E., and C. W. Walton, M. Am. Soc. C. E., were accepted.

A Committee of the Board was appointed to take up the matter of a proposed revision of the rules for the award of the Collingwood Prize for Juniors.

Applications were considered, and other routine business transacted.

Three candidates for Associate and seventeen for Junior were elected.*

Adjourned.

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* See page 40.

REPORT IN FULL OF THE FIFTIETH ANNUAL MEETING, JANUARY 21st and 22d, 1903.

Meeting called to order.

Wednesday, January 21st, 1903.—The meeting was called to order at 10:45 A. M.; Vice-President C. C. Schneider in the chair; Charles Warren Hunt, Secretary.

THE CHAIRMAN.—The minutes of the meeting of January 7th, 1903, will be printed in the January number of *Proceedings*, and come up in due course for action at the meeting of February 4th. In view of this fact, the reading of those minutes will be dispensed with, if there are no objections.

Tellers appointed.

The time has arrived now for canvassing the votes for officers, and I will appoint Messrs. G. S. Stoddard and C. D. Pollock as tellers. The ballot will be closed, in accordance with the Constitution, at twelve o'clock noon. Any member present who has not voted may vote, up to that time. In order to finish the count of the ballot in time, the tellers may proceed at once with the count.

The next business is the reading of the report of the Board of Direction for 1902.

Report of the Board of Direction.

The Secretary read the report of the Board of Direction.*

THE CHAIRMAN.—You have heard the report of the Board of Direction. What action will you take?

A MEMBER.—I move that the report be received and placed on file.

Seconded and carried.

THE CHAIRMAN.—The report of the Secretary to the Board of Direction.

The Secretary read his report.†

THE CHAIRMAN.—You have heard the Secretary's report. What action will you take in reference to it?

It was moved and seconded that the report be received and placed on file.

Carried.

THE CHAIRMAN.—The report of the Treasurer.

The Treasurer read his report.‡

THE CHAIRMAN.—Gentlemen, what action will you take with reference to the Treasurer's report? If there are no objections, it will be received and placed on file.

Reports of Special Committees.

The report of the Special Committee on Uniform Tests of Cement, Mr. Geo. S. Webster, Chairman.

Report read by Mr. Webster.§

(At 11.20 A. M. the chair was taken by the President, Mr. Robert Moore.)

THE PRESIDENT.—You have heard the report, and it is now open for discussion or for such action as the meeting sees fit to take.

* See *Proceedings*, Vol. xxix, p. 5 (January, 1903).
† See *Proceedings*, Vol. xxix, p. 12 (January, 1903).
‡ See *Proceedings*, Vol. xxix, p. 14 (January, 1903).
§ See *Proceedings* for January, 1903.

J. JAMES R. CROES, Past-President, Am. Soc. C. E.—I move that the report be received and printed in the *Proceedings*, and the Committee continued.

Seconded and carried.

E. B. CODWISE, M. Am. Soc. C. E.—I move that the Committee be thanked for their labor and their report.

Seconded and carried.

THE PRESIDENT.—The next thing in order is the report from the Committee on Rail Sections; Mr. Bouscaren, Chairman. I believe he has a progress report.

The report was read by Mr. Bouscaren as follows:

"The Special Committee on Rail Sections would report that it has made progress in its labors; has been and is in correspondence with the Chief Engineers of many of the railroads of the United States and Canada; and that the reports received from them show greater proportionate wear of the heavier than of the lighter sectioned rails.

"They would also report that the steel rail manufacturers of the United States have appointed a committee to act in consultation with your committee, and that one joint session has been held. Your committee asks to be continued."

" G. BOUSCAREN,
" *Chairman.*"

THE PRESIDENT.—You have heard the report, gentlemen, and also the request of the Committee that they be continued. What action will you take?

MR. CODWISE.—I move that the request be granted.

Seconded and carried.

Nominating Committee.

THE PRESIDENT.—The next order of business is action upon the nominations for the seven geographical districts for members of the next Nominating Committee. We will hear the reports of the nominations which have been made by the members of those districts.

THE SECRETARY.—The report from District No. 1 is as follows:

District No. 1.—Total number of votes received, 98; distributed as follows:

GEORGE W. TILLSON	24
FREDERICK S. ODELL	19
HENRY W. HODGE	16
C. H. GRAHAM	3
GEORGE S. RICE	3
J. V. DAVIES	2
J. J. R. CROES*	2
GEORGE B. FRANCIS	2
CHARLES S. GOWEN	2
ALLEN HAZEN	2
O. F. NICHOLS	2
T. KENNARD THOMSON	2
S. C. THOMPSON	2

*Ineligible.

Nominating Committee (Continued).

The following have received one vote each:

Wm. Henry Baldwin,	Edward P. North,
William H. Burr,	John F. O'Rourke,
S. L. F. Deyo,	E. E. Olcott,
William B. Fuller,	J. Waldo Smith,
Martin Gay,	M. G. Starrett,
S. W. Hoag, Jr.,	Edward Wegmann,
George A. Just,	S. C. Weiskopf,
Henry P. Morrison,	W. J. Wilgus,*

F. Stuart Williamson.

The Secretary.—The members of the Nominating Committee are to be elected by this meeting, and this is merely a suggestion to the meeting.

The President.—The Chair awaits suggestions in that matter, as to the pleasure of the Society.

J. M. Knap, Treasurer, Am. Soc. C. E.—I move that the usual course be adopted, and that we elect the man who receives the largest number of votes, who, I think, in this case, is Mr. Tillson.

Seconded.

The President.—It is moved and seconded that Mr. Tillson be the choice of the meeting for this district.

Carried.

The Secretary.—From District No. 2 the report is as follows:

District No. 2.—Total number of votes received, 42; distributed as follows:

J. P. Snow	11
Clarence B. Vorce	8
George A. Kimball*	4
Frederic P. Stearns	4
C. Frank Allen	2
S. E. Tinkham	2

The following have received one vote each:

A. S. Cheever,	George R. Hardy,
Freeman C. Coffin,	C. M. Ingersoll,
Desmond FitzGerald,*	Leonard Metcalf,
George B. Francis,*	Mace Moulton,
Arthur W. French,	Edward Sawyer,

George F. Swain.*

C. S. Allen, M. Am. Soc. C. E.—I move that Mr. J. P. Snow be elected on the Nominating Committee.

Seconded and carried.

The Secretary.—The District No. 3 report is as follows:

District No. 3.—Total number of votes received, 66; distributed as follows:

Edward A. Bond	29
Palmer C. Ricketts	19
Charles M. Morse	2
P. Alexander Peterson	2
Gardner S. Williams	2

* Ineligible.

The following have received one vote each:

JOHN F. ALDEN,*	JOHN KENNEDY,
FRANK V. E. BARDOL,	LOUIS H. KNAPP,
E. E. BRYDONE-JACK,	OLIN H. LANDRETH,
ROBERT CARTWRIGHT,	E. H. MCHENRY,
CLARK FISHER,	ELNATHAN SWEET,
WILLIAM A. HAVEN,	T. W. SYMONS.

THE PRESIDENT.—Is there any motion?

MR. E. B. CODWISE.—I move that Mr. Edward A. Bond, having received the highest number of votes on the ballots, be declared elected.

Seconded and carried.

THE SECRETARY.—The ballot from District No. 4 is as follows:

District No. 4.—Total number of votes received, 107; distributed as follows:

RICHARD KHUEN, JR	47
L. Y. SCHERMERHORN	22
H. M. WILSON	17
BERNARD R. GREEN	2
EMIL SWENSSON	2

The following have received one vote each:

EDWARD M. BIGELOW,	N. H. HUTTON,
WILLIAM BRADFORD,	HARVEY LINTON,
W. W. CARD,	F. O. MAXSON,
ARTHUR P. DAVIS,	MANSFIELD MERRIMAN,
GEORGE S. DAVISON,*	WILLIAM A. PRATT,
J. E. GREINER,	E. B. TAYLOR,
G. B. HAZLEHURST,	S. LA R. TONE,
JOHN W. HILL,	SAMUEL TOBIAS WAGNER,*

GEORGE S. WEBSTER.

THE PRESIDENT.—Richard Khuen has the largest number of votes. It is moved and seconded that his election be made unanimous. Carried.

THE SECRETARY.—District No. 5 votes:

District No. 5.—Total number of votes received, 79; distributed as follows:

L. E. CHAPIN	25
J. B. DAVIS	8
WILLIAM M. HUGHES	6
R. B. C. BEMENT	3
G. A. MARR	3
JOHN W. ALVORD	2
CHARLES E. GREENE	2
D. W. MEAD	2
C. J. A. MORRIS	2
SAMUEL T. WELLMAN	2

* Ineligible.

Nominating Committee (Continued).

The following have received one vote each:

WARD BALDWIN,	CHARLES F. LOWETH,
L. F. G. BOUSCAREN,*	RALPH MODJESKI,
GEORGE H. BOYNTON,	G. B. NICHOLSON,*
W. M. CAMP,	WALTER P. RICE,
D. D. CAROTHERS,	H. E. RIGGS,
E. C. CARTER,*	JAMES RITCHIE,
CLARENCE COLEMAN,	J. W. SCHAUB,
F. A. DELANO,	E. C. SHANKLAND,
JAMES DUN,	CHARLES L. STROBEL,
R. L. ENGLE,	JOB TUTHILL,
E. E. HASKELL,	L. L. WHEELER,
G. W. KITTREDGE,	GEORGE Y. WISNER.

On motion, duly seconded, Mr. L. E. Chapin was elected as member of the Nominating Committee.

THE SECRETARY.—District No. 6:

District No. 6.—Total number of votes received, 46; distributed as follows:

JOHN B. ATKINSON	5
ARTHUR HIDER	3
J. A. L. WADDELL	3
GEORGE G. EARL	2
L. F. GOODALE	2
B. M. HARROD	2
C. D. PURDON	2
S. BENT RUSSELL	2

The following have received one vote each:

JAMES P. ALLEN,	D. W. LUM,
WILLIAM CAIN,	R. C. MCCALLA,
W. W. CARSON,	HUNTER MCDONALD,*
WILLIAM H. COURTENAY,	F. A. MOLITOR,
WILLIAM P. CRAIGHILL,	R. MONTFORT,
BEN. L. CROSBY,	GEO. B. NICHOLSON,
EDWARD FLAD,	J. A. OCKERSON,
B. M. HALL,	M. P. PARET,
W. J. HARDEE,	HIRAM PHILLIPS,
W. N. HAZLEHURST,	A. M. SCOTT,
E. C. LEWIS,*	B. F. THOMAS,
J. L. LUDLOW,	C. C. WENTWORTH,

JOSÉ R. VILLALON.

THE PRESIDENT.—Mr. John B. Atkinson has the largest number of votes. Is there any motion? If not, those who are in favor of the election of John B. Atkinson will say aye.

Carried.

THE SECRETARY.—District No. 7:

* Ineligible.

District No. 7.—Total number of votes received, 44; distributed as follows:

D. C. Henny	9
C. E. Grunsky	4
C. D. Marx	4
Roberto Gayol	2
Horace A. Sumner	2
A. J. Tullock	2
Otto von Geldern	2

The following have received one vote each:

W. A. Aycrigg,	C. E. Fowler,
Julius Baier,	Arthur DeWitt Foote,
R. E. Briggs,	F. W. D. Holbrook,
R. B. Burns,	John D. Isaacs,
E. B. Cushing,	W. H. Kennedy,
George L. Dillman,	J. B. Lippincott,
H. W. Edwards,	J. W. Maxey,
C. F. W. Felt,	D. W. Ross,
W. W. Follett,	W. B. Storey, Jr.,

James D. Schuyler.*

The President.—Mr. D. C. Henny has the largest number of votes. Those who are in favor of making him a member of the Nominating Committee signify by saying aye.

Carried.

Award of Prizes.

The President.—This concludes that order of business. The next is the report from the Board of Direction as to the award of the medal and prizes for the year ending with July, 1902.

The Secretary.—I am directed by the Board of Direction to report that the Norman Medal and the Thomas Fitch Rowland Prize have been awarded by the Board, in accordance with the recommendations of the following report:

To the Board of Direction,

American Society of Civil Engineers.

The undersigned respectfully recommend that awards of the Normal Medal and Thomas Fitch Rowland Prize for the year ending with the *Transactions* for July, 1902, be made as follows:

The Norman Medal to Paper No. 911, "Experiments at Detroit, Michigan, on the Effect of Curvature upon the Flow of Water in Pipes," by Gardner S. Williams, M. Am. Soc. C. E.; Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 910, "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government," by William W. Harts, M. Am. Soc. C. E.

* Ineligible.

Award of Prizes (Continued).

There being no papers contributed exclusively by Juniors, no recommendation as to the award of the Collingwood Prize for Juniors can be made.

Respectfully submitted,

H M. CHITTENDEN,
BERNARD R. GREEN,
G. BOUSCAREN,
Committee.

THE PRESIDENT.—This is simply for information, and requires no action. The next order of business is the proposed amendment to the Constitution, which the Secretary will read.

Proposed Amendment to the Constitution.

THE SECRETARY.—This amendment to the Constitution has now gone through all the forms, and this meeting has the power to amend it and send it out as amended; if it is not amended at this meeting, it goes to the Society in the form in which it is at present.

Amend Article III of the Constitution as follows:

Section 2, first line, after the words "Society as" strike out the words "Member or as Associate" and insert the words "a Corporate"; second line, after the word "to" strike out the words "either grade of."

Section 2, Art. III, will then read, "An application for admission to the Society as a Corporate Member, or for transfer from any other grade to Corporate Membership shall embody," the rest of the section standing as now.

Section 3, third line, after the word "membership" strike out the words "in any grade," and after the word "transfer" strike out the words "from one grade to another"; twelfth line, for the word "may" substitute the word "shall." The section will then read as follows:

"At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for membership or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of the references in the case of Corporate Member, and endorsers in the case of Associate, Junior or Fellow, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on applications for Corporate Membership may direct a ballot."

THE PRESIDENT.—The matter is open for discussion, gentlemen.

J. F. O'ROURKE, M. Am. Soc. C. E.—I would like to offer this amendment as a substitute for the amendment just read.

The Secretary read the amendment offered, as follows:

Proposed Amendment to the Constitution.

Amend A ticle III of the Constitution as follows:

Strike out the first seven sections of Article III, and substitute the following:

1. Election to membership in all grades shall be by the Board of Direction, subject to the following procedure:

2. Honorary Members shall be proposed by at least ten members, and shall be elected only by a unanimous vote of the Board of Direction. A Past-President, or a member of the Board of Direction proposed for Honorary Membership, shall not be required to vote either for or against his own admission.

A person elected an Honorary Member shall be promptly notified thereof by letter. The election shall be canceled if an acceptance is not received within six months after the mailing of such notice.

3. Members, Associate Members, Associates, Juniors and Fellows, shall be elected by letter-ballot of the Board of Direction, and on such ballot three negative votes shall exclude.

4. An applicant for admission to the Society as Member or as Associate Member, or for transfer from any other grade to either grade of Corporate Membership, shall embody a concise statement, with dates, of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected. The applicant shall furnish the names of at least five Corporate Members to whom he is personally known. Each of these shall be requested by the Secretary to address a letter to the Board of Direction, on a form prescribed by said Board, stating the extent of the writer's personal knowledge of the applicant and of his professional work. If at least five of the Corporate Members named as references do not furnish the requisite endorsement, the Secretary shall call upon the applicant for additional names, and not until written communications shall have been received from at least five Corporate Members shall the application be considered by the Board.

Applications of engineers not resident in North America, and who may be so situated as not to be personally known to five Corporate Members, may be endorsed by five Members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

5. An application for admission as Associate, Junior, or Fellow, shall embody a statement of the applicant's qualifications for the grade of membership for which admission is sought. The application shall be signed by the applicant, and endorsed by at least three Corporate Members who shall certify that they personally know the applicant, and believe him to be in all respects a proper person to be admitted to the Society, and that they recommend him for admission.

6. At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all applications received, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references in the case of Corporate Member, and endorsers in the case of Associate, Junior or Fellow, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. The names of applicants for admission as Member or Associate Member shall be

Discussion on Amendment to the Constitution (Continued).

alphabetically arranged as applicants for Corporate Membership, without specification as to which of these grades is sought. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received, and may then proceed to letter-ballot. The Society shall be notified of all elections.

Change the numbers of Sections 8, 9, 10 and 11 to 7, 8, 9 and 10, respectively.

B. R. GREEN, M. Am. Soc. C. E.—I second the amendment.

THE PRESIDENT.—This amendment has been offered and seconded, and is now open for discussion or action by the meeting.

A MEMBER.—Is it the intention of taking the vote on the amendment to the Constitution, or the amendment to the amendment, to-day?

THE PRESIDENT.—The amendment to this proposed amendment is pending.

A MEMBER.—As an amendment to the Constitution?

THE SECRETARY.—It requires a letter-ballot of the whole Society; action by this meeting is merely on the form in which the amendment shall be sent out.

P. C. RICKETTS, M. Am. Soc. C. E.—Mr. Chairman, it seems to me that the adoption of this amendment to the original amendment would be the defeat of the original amendment. This question of the election of members by the Board of Direction has been thoroughly considered in the past two or three years. There was a committee, as you recollect, appointed, and that committee reported, and it was defeated, as I remember, by the Society.

Now, it seems to me that the amendment proposed to-day is a good one, that is, that the classification shall be made by the Board of Direction; but the amendment to this amendment is not, in my opinion, a good one. I do not believe that the Board of Direction should have the entire charge of the affairs of the Society. I believe that, as far as the election of members of the Society is concerned, the Society is the best judge. It is true that every now and then a pink ballot comes out. They look very pink and they make an impression, but the committee appointed found—I forget the exact number, but I think it was something like thirty-two pink ballots in four or five years. It seems to me that the present method of electing members is a pretty good method and a pretty safe method. We all have a chance, those of us who are interested, to scan carefully the blue lists as they come out, and afterward the ballots, and can use our own judgment; and it is a pretty good, democratic way of doing things.

I think it would be a mistake to adopt this amendment to the amendment proposed.

H. G. PROUT, M. Am. Soc. C. E.—Mr. President, as the Chairman of the committee which originally produced the amendment which

has been circulated among you, it may be well for me to say two or three words. The intention of the work of our committee was simply to put the classification in the hands of the Board of Direction, as Professor Ricketts has pointed out. That is all we wished to do. We held that the Board of Direction had that power already, under the Constitution, but it did not seem quite clear that that was the case, and, therefore, the amendment which we proposed was designed to make that clear; that it was not only within the power of the Board of Direction to classify candidates, but that it was their duty. That is what our amendment was aimed to accomplish.

The amendment to that amendment which is brought forward now accomplishes that purpose, and it goes further, and puts the election in the hands of the Board of Direction. So far as that goes, I do not agree with Professor Ricketts. For many years I have held very stoutly the position that he has taken, namely, that the election should be in the great body of the Society, but within the last two or three years my feeling has changed, and I have come to believe that it would be better for the Society if the election of members were in the hands of the Directors. I should imagine that it would increase the sense of responsibility of every person who was directly interested in the election; that is to say, each member of the Board of Direction would feel that the responsibility was upon him of doing precisely the right thing. He could not soothe his conscience by knowing that there is another body to come after him, to confirm or reject his action, and surely the Board of Direction can know more precisely the fitness or unfitness of the candidate than can the great body of the members.

It is extremely difficult, I know, to get to a large body precise information very quickly, and especially negative information; but that need not be so. The Board of Direction can organize its machinery in such a way as to get more precise information, we will say, by appointing some committees among its own members to cover different territories, and take pains to get information about candidates; and my own feeling now is quite strong that the Society would get better results by having the election put in the hands of the Board of Direction.

Foster Crowell, M. Am. Soc. C. E.—Mr. Chairman, I would also support the amendment to the amendment. The matter has been before the Society quite frequently, as one of the previous speakers has mentioned, and it seems to me that this presentation is an evidence of profound reflection upon the discussions that have gone before.

Having had the opportunity to support the general idea of the policy of the election of members by the Board, in the past, I have had my feelings confirmed that that is the most practical, exact and proper method of selecting the proper material. It is not my inten-

Discussion on Amendment to the Constitution (Continued).

tion to go into details at this time, but to point out that, with the present arrangement, when the pink ballot is sent out, there is always a strong effort, on the part of the friends of the candidate, to secure favorable action, upon the mere statement of their belief that the candidate is worthy. That has the effect of making the pink ballot entirely ineffectual, and there is no other reason that I can see—if you admit that the pink ballot is, to that extent, valueless—for keeping the election of members in the hands of the members of the Society, as at present.

On the other hand, the opportunity which the Board has of arriving at an accurate estimate of the candidate's character and abilities is so very much greater that it seems to me there is no choice in the matter, and I hope that the amendment will pass

MR. RICKETTS.—Mr. Chairman, Mr. Crowell has stated one view of the question. The other view is this: That a great many members of the Society will not write or give their opinions of the candidates to the Board of Direction, partly because they would be unable, perhaps, to prove definitely their opinions of the man, and, secondly, because they are afraid that members of the Board of Direction would give to the candidates information which had been presented to the Board of Direction.

Now, gentlemen, that thing occurs. Within my knowledge, there has been, within the last two years, a man presented for membership in this Society who was unfit for the position. He was first sent out by the Board of Direction to be voted upon, and was blackballed. He was then sent out again on a pink ballot, and was defeated. He was not a fit member of the Society. He would have been elected, if the election had been in the hands of the Board. They sent it out twice, and the members would not receive him.

Now, that is the other side of that question. And I also know, of my own knowledge, that members of the Board have given information to candidates for membership in this Society—information which they had no right to give. Now, that is the other side of this question. I do not mean to cast any reflections on the Board of Direction of this Society, as a whole. I have been a member of the Board, and I am proud of it, and I do not believe there are any better men in any profession who could be collected together than the members of the Board of Direction of this Society; but I do not believe they give often sufficient consideration, as a Board, to the question; and I do not believe that a man in California, if a pink ballot is sent to him, will give very much more consideration to it than he does at present. I think it is a perfectly safe proposition to leave that matter in the hands of the members of the Society as a whole. (Applause.)

MR. O'ROURKE.—Mr. Chairman, I have been a member of the

Society for nineteen years, and I have just completed a term as a Director. During my term in the Board, when Professor Ricketts was there, I nearly always had the pleasure of being on the same side with him, and I am sorry to see that, having left the Board, he does not continue on the right side of the question.

THE PRESIDENT.—I am informed that it is twelve o'clock, and this is the hour at which the ballot is closed and counted by the tellers.

MR. O'ROURKE.—The speaker's objection seems to be largely due to the fact that the Board of Direction is a fallible body, and that, to some extent, the door is ajar, and now and then information will get out. Well, that may be true; I don't know but what it has gotten out. I can only say that, in regard to the general practice, everything that goes to the Board remains there and never gets beyond. It may be that there are individual instances where that has occurred; that will happen anywhere, and when we can get enough sense together to make a Board of Direction that is infallible and all-wise, then the Professor's idea probably will be reached in regard to what a Board ought to be ; but as long as we cannot get any further than to select from among the body of the American Society of Civil Engineers the best men that are found in it, and make them the Board of Direction, we have got to put up with whatever difficulties may arise from the fact that they are not absolutely perfect.

Now, to get to the regular question: We are not discussing something that is proposed by the American Society of Civil Engineers as a new policy of the Society and a new way of electing its membership, and of being democratic or not being democratic—get away from that idea of democracy which seems to be so popular with some, and with all of us, I hope—but the only thing is we have got to find out how democratic we are. There is no body, of the description of this Society, which asks the general membership to elect its members.

This Society is probably six times larger than it was when I came into it, and the difficulty at that time was that the members were unable to vote intelligently, and that a few would get together, and, from prejudice, or for some other reason, shut out a man who was absolutely worthy. In spite of everything, the Society has grown, so that to-day, not to be a member of the Society, or to be rejected by the Society, by seven unknown voters out of two thousand, who may or may not be acting right, is a stigma; and the reason why people are rejected, very often, is not that they are unworthy, but simply because there are certain people who do not like them; and the more a man is known, while there are more people who like him, no matter how many may like him, they do not make any difference if there are seven who do not like him, however unworthy their motives, or however worthy, if you will, the other two thousand may be, their approval is of no value whatever.

Discussion on Amendment to the Constitution (Continued).

A MEMBER.—You would not get in now.

MR. O'ROURKE.—No, I would not have the least chance. One of the things that I would like to call attention to, in this amendment, is that it is a letter-ballot of the whole Board, and that three votes against any member reject. Now, that lets out all this thing about, "if the Board of Directors had the voice when this unworthy person was turned down in the pink ballot, he would have got in." It does not follow. There might have been three men on that Board who had sense enough to turn down a man asking to come in. That is not asking too much from this fallible Board which is not perfect. We may get three just men there. Who can tell?

What can be more ridiculous, Mr. Chairman, and Gentlemen, than to stand here and say that it is a democratic method that we have now, and that it ought to be kept up in spite of the fact that the experience of every other body, and our own experience, proves that it is wrong. Who votes and has a voice in favor of anybody? No, you can go to the Board of Direction with your troubles, if you have them, in regard to candidates, and the Board will carefully consider whether your troubles are real or not. You can go to your six bosom friends and say you do not like somebody, and he is rejected; and the Society stands helplessly by and sees him shut out. You can send out your pink ballots, and what do you get? You get ten or fifteen people who vote against every pink ballot, and then you get the great body voting on the pink ballot when they don't vote on the white ballot, and they don't vote on the pink ballot unless a special effort is made to bring out the vote.

I remember when the discussion was had, about ten years ago, on this pink ballot. It was supposed that when a wrong was done, everybody would be eager to right it. It has come to be so that not one-tenth of the members vote now for anyone; and the pink ballots don't have anything to do with it. They say: "We don't know." The result is that unless efforts are made to bring out the votes, less than 10% of the body votes, and 10% of that rejects. So, after all, with the pink ballot, unless you make an effort, 1% is a matter of rejection.

This thing of mistrusting your Board, and to have that mistrust expressed by a man who himself has been a member of the Board, and knows the absolute slavery of the membership of being a member of the Committee on Admissions—I never saw anything like it, gentlemen. I have never seen anything like the way in which the letters are weighed, and the evidence is taken against anybody. Unless there is the strongest appearance of injustice, and unfairness, and want of truth, in the objections that are raised against a man, the policy of that Committee on Admissions—and I have seen that Committee changed through three years—its policy is always to give the Society the benefit of the doubt against a man. In other words, the Society

will keep every one out who cannot prove his title clear, as far as the Board of Direction is concerned. How is it with the outside parties? The people who waste two cents on a white ballot that does not contain a blackball are simply *nil;* and most of them know it.

Now, take any body: Does the Institution of Civil Engineers elect its members through the general body? Do any of the large clubs do it? Do any of the small clubs, even, do it, without making trouble for themselves?

The only way you can consider a man justly, in view of the rights that every engineer professionally qualified has to membership in the Society, whether we like him or not, if he is worthy otherwise, that can be protected by the Board of Direction, and it cannot be protected by putting it into the power of any seven—sellers of material, who, to get an order, any old thing at all does for an excuse to keep a man out, so long as they don't have to stand behind it, and I say seven will answer. I say it is the opposite of democracy; it is the opportunity for unfairness, and it is the opportunity for sneakery. (Applause.)

Mr. Green.—Mr. President, may I ask how the Board of Direction determines its action as to the sending out of either the white or the pink ballot. Isn't it done by a majority of the Board, the majority action of the Board? How many votes in the Board are sufficient to prevent the sending out of a pink ballot, or what is the action?

The Secretary.—It depends upon the number of members present at a meeting.

Mr. Green.—And the majority of those?

The Secretary.—The majority of those. I might say that the difference, if you will allow me a minute, the difference between the action of the Board under this proposed amendment, as I understand it, and the present action of the Board, in the case of applicants for membership, is that the action is taken at a meeting now where five members constitute a quorum, and by a majority; whereas, under the amendment, this is by a letter-ballot of the whole body, as I understand the amendment.

Mr. Green.—I am asking how the Board now decides ballots; I think it is done by a majority of the Board.

The Secretary.—Not a majority of the Board, but a majority of those present.

Mr. Green.—By a majority of those present. Then I would say to Professor Ricketts that it might be very likely that the Board, in sending out either the white or the pink ballot, may have voted unanimously on it, and that if a minority, or at least a sufficient minority in that Board, which, under the proposed amendment to the amendment, say, three votes, had existed, that white ballot would not have gone out in the first place, and probably the pink ballot would.

Discussion on Amendment to the Constitution (Continued).

The point I make is that, under the proposed amendment to the amendment, a small number of negative votes in the Board will defeat any candidate. That is not possible now. A small number of votes, under this proposition, would defeat any candidate, would it not?

THE SECRETARY.—Yes, sir.

MR. GREEN.—That would be a minority of the Board, if seven members were present. I was a member of the Committee, last year, which reported against the proposed amendment of this kind. I was the one minority member. It would, perhaps, be interesting for the Society to know that that Committee never held a personal meeting. There was but one other member upon the Committee with whom I was personally acquainted. The way we came to make the report was through a very little correspondence, and I did feel that some of my colleagues might not have had the opportunity to familiarize themselves with this question, as they would have had if we had got together and talked it over.

I believe that this proposed amendment is a most excellent thing, on general principles. Both Mr. Prout and the proposer of the amendment have stated my views of the thing very fairly. It is not a very important question, as far as the expense is concerned, but it seems to me that the Board of Direction has practically and entirely the whole thing in its own hands now, and when the majority of that Board decides to send out a letter-ballot, let it go out, and the members of the Society vote on it with what little light they have, which is very little, usually; and when they decide to send out the pink ballot, it is the same way; they have come to the best conclusion they can, by the majority, and then they have to throw the whole thing over to the Society to be acted upon with but very little knowledge, and very few votes come in. It seems to me to be a very clumsy arrangement, and that it would simplify matters very much, and be much to the advantage of the Society if the Board should attend to the whole matter. It would feel the responsibility more keenly. It can act upon the nominations for membership most intelligently, and it will not be obliged to throw anything upon the Society when unable to conclude the matter in a Board meeting unanimously.

GEORGE HILL, M. Am. Soc. C. E.—Mr. Chairman, there has been one criticism made which, in my experience, is not well founded. I know that, in my own experience, in obtaining admission to the Society, opposition was met which never dared show its head, and that opposition was kept up among the membership. It was simply a matter of personal prejudice, and was finally overcome. I have had other members of the Society request me to vote against members for admission, for reasons which I am very sure those men would not put on paper, and sign with their own names and submit to the Board of Direction; that is to say, for purely personal reasons in no way connected either

with the personal fitness of the candidate to be a member of the Society, or with his professional qualifications.

The Board of Direction will occupy the position of a jury, and will waive all good reasons against the promotion or the admission of a candidate. They are best fitted to perform that function, because membership in this Society is not and should not be gauged by the man's personal acceptability to the various members of the Society, but by his professional qualifications, and his personal cleanliness. This is not a social club, where those who are in it are to determine upon the availability of those who are to come in, according to their personal acceptability, but it is a Society, as has been stated, where the only qualifications are personal cleanliness and professional standing, and for that reason the personal element ought to be eliminated as far as possible.

This proposed amendment is nothing more than the logical development of the method of admitting members to the Society, which has been a matter of slow growth, year by year, modified from time to time, in order to meet the conditions as they arise. It has now reached the point where it should be the belief of every thinking member of the Society that the change is an absolute necessity in order to secure the best work of the Society for itself.

In regard to the action by the Board on the application of candidates, I know, of my own knowledge, that the Board does give consideration to the voice of the members. I know of a case where an applicant whose name was sent out on the blue list never got any further. What the action of the Board was, I don't know. I do know that I wrote out what I thought of that candidate, signing my name to it, and sent it to the Board, and I know that the name did not go out to the voters. Whether that was backed up by anybody else or not, I don't know. My objection to that man was simply on his professional qualifications.

At 12.15 P. M. Past-President J. James R. Croes took the chair.

ROBERT MOORE, President, Am. Soc. C. E.—Mr. Chairman, I cannot let a matter of this importance pass without having another proposition which has been made, in this regard, brought at least to the attention of the meeting. The matter itself is one of the very greatest importance. The method of selecting our membership is certainly one that cannot be exceeded in importance by any subject that can be brought before this body.

The present method, while, in the main, it has worked satisfactorily, I think, has not worked satisfactorily in all cases. There have been, undoubtedly, malicious and unjustifiable exclusions from the Society. I have not the experience that many of those who have served practically upon the Committee of Admissions have had, but I know that this is the fact. Now, the remedy for that, which is suggested

Discussion on Amendment to the Constitution (Continued).

by this amendment to the amendment, is to revolutionize completely the former plan, and to throw the whole matter into the power of the Board of Direction.

Now, there is another suggestion which, I think, was made to this meeting a year ago, which, so far as I know, was first brought before a meeting of the local members of the American Society of Civil Engineers at St. Louis, which was to solve the difficulty, not by throwing the election into the Board of Direction, but by increasing the number of negative votes required. Now, in a membership as large as ours, I think it may be admitted that seven votes, which is but a fraction of 1% of the total number of Corporate Members, is too small a number, and that it needs to be remedied in some way, and the suggestion at that time—and I think it is a suggestion which has been canvassed in the Board of Direction—was that the number be increased to approximately 1% of the total number of Corporate Members, which, at the present time, would be twenty or twenty-one.

Now, I think a great many members, perhaps not as well informed as some others, would prefer a method of that kind to one which is so entirely revolutionary as the one which has been suggested by Mr. O'Rourke's amendment, and I think that this plan ought to be brought to the attention of this meeting. This matter was considered by a Committee of the Board of Direction, I believe not approved by the Board of Direction, but a report was made which substantially embodies that idea, and, personally, it seems to me that it would be probably the best action to take at the present time. It seems to me that it would probably cure nine-tenths, if not the whole, of the malicious blackballing, which is now complained of, and which is sought to be remedied, and if so, it would, I think, be a safer remedy, and one which would greatly relieve the Board of Direction of the responsibility, which they certainly are not anxious to take, of bearing the whole burden of the election of members to the Society.

The gist of this proposed other plan is contained in this clause:

"The ballots shall be letter-ballots, in a form to be prescribed by the Board of Direction. They shall be mailed to each Corporate Member whose address is known, and shall state the date on which the ballot is to be canvassed, and which shall be not less than twenty days after the issue of the ballot. Twenty or more negative votes shall exclude from election."

If that twenty were made 1% of the Corporate Members, as at the time being, or at the time of the last list of membership, I think that it would go a long way toward curing the trouble which is now sought to be remedied.

MR. O'ROURKE.—Mr. Chairman, in relation to what Mr. Moore has just read, the report of that committee was made to the Board of Direction, and the reasons given by the committee were much the same as those given now by Mr. Moore for making that report. It

was not that they considered it the best action, but they considered it the action that would be most likely to meet the difficulty, and at the same time meet with the approval of the general body and of this meeting. In other words, they believed that what my amendment to the amendment embodies was the best. It was passed upon by the Board, and approved by the Board as a substitute for this action of their own committee, and, as I am no longer a member of the Board, it was thought that it would be perfect good taste in having it presented by me, not as being the action of the Board, but it was their belief that it was the proper thing to do.

Mr. Moore, himself, states that it is not the best thing to do, this election of members by an uninformed body, as it is absolutely impossible to inform that body as to the qualifications of anybody, and right was considered as something; but they had this belief, which I do not believe, even though this meeting votes against this amendment.

My belief is that the Society wants to do what is right, even when it is radical, and the right thing to do is what every other Society does, elect your members by a body which is qualified to do it, by the knowledge which is brought to them, and by the knowledge which they themselves possess, and that is why this suggestion cannot be considered ; for, of course, we cannot consider an amendment to an amendment, because you have either to accept or reject that amendment to the original amendment proposed as it is offered, and if you don't want to do anything radical, and rather prefer to do something which is half right and partly radical, why it is up to you to do it that way. (Applause.)

C. F. Allen, M. Am. Soc. C. E.—It seems to me that the gentleman who has proposed the amendment to the amendment has come near proving too much. He rather protests that the Board of Direction ought to be trusted. Why doesn't he protest that the Society ought to be trusted? Why can't you trust the Society as well as trust the Board of Direction?

I believe you can, but the objection is urged that there are some bad members in the Society. How did they get there? They went by the Board of Direction, if they got there at all.

Now, there is no way of doing this thing right. There is no way of handling it, so far as I can see, in which the action will be satisfactory. If you entrust it to the Board of Direction, the work will not be efficiently done. Men will go by who ought not to go by. If you entrust it to the Society, men will be rejected who ought not to be rejected. There is no escape from those propositions, it seems to me.

Not many years ago, in talking upon this particular matter, I talked with a member of the Society who had been in the Board of Direction, the Chairman of the Board of Direction—a man in high

Discussion on Amendment to the Constitution (Continued).

esteem in the Society—and his criticism was that it was undesirable that the matter should be thrown into the Board of Direction; that, in his experience, the action of the Board of Direction at times had been such that it was unwise to put the whole matter into its hands. It certainly is true that cases, as he suggested, had gone by, had gone through the Board of Direction, that ought not to. Certainly, members have been at first rejected, and have been again rejected, when they ought not to have been rejected.

We then, substantially, meet the proposition, what shall we do? Shall we take the chance of shutting out a good man, or shall we take the chance of letting in a bad man? I believe that we want to resist the chance of taking in the bad man. I believe that it is a mistake, on the whole, to take the affair out of the hands of the members.

It is perfectly true, as one of the previous speakers has stated, that I, or other members, may be entirely satisfied, but it may be absolutely impossible for us to prove, that he is an undesirable member, and yet our instincts are so clear and right, upon the best motives, upon the best qualifications for membership, that the ballots ought to be cast against the candidate.

It is said that seven bad members may cause the rejection of a good candidate. Why can't five members, who are the only members who know an applicant—five bad members—why can't they put the man into the Society? Where does the Board of Direction get its information, except from those five men?

There are a good many sides to it, I believe, and we want to hesitate before we take the power from the hands of the individual members, who, locally, are able oftentimes to have facts, which are the proper thing as the basis of admission—some of the people, locally, may have facts that do not really come to the Board of Direction. The Board of Direction has a good deal to do; they are busy men; they are not able always to get at the facts definitely. (Applause.)

J. N. Greene, M. Am. Soc. C. E.—Mr. Chairman, I want to ask Mr. O'Rourke, as a matter of information, how the Board of Direction gets information and knowledge as to candidates for this Society, and gets information which is definite enough, and positive enough, to settle this question whether a man shall be admitted or not?

Now, I cannot see, from the debate, as far as it has gone, any plan, and I ask Mr. O'Rourke, in having been a member, what is the *modus operandi* at present, if any, which is taken to find out the qualifications of a candidate when he asks to be admitted to this Society?

Mr. O'Rourke.—Mr. Chairman, the *modus operandi*, so to speak, is to send out a blue list, notifying the whole body of the Society of the application of the person for membership, and requesting confidential information. That is done to-day. That information goes to the Committee on Admissions, and I have known cases where four men, and

often more, were turned down by the Committee on Admissions at a single meeting, due to the evidence that was received as to the unworthiness of the applicant; and, further, if information is received against anybody which does not bear the stamp of truth on it, the Committee on Admissions, though they are busy men, go further into the matter. The name is put back, and put back, and put back, until they are fully satisfied. They take cognizance of the right of the good man to come in, as well as the right of the Society to exclude the bad, and that is something that cannot be done by the body at large, and that is something that it does not do to-day. It does not vote; it does not consider. Only those who have anything to say against anybody—and their saying is merely a black mark—those are the ones who really communicate anything to the election, and, further, Mr. Chairman, that is considered afterward by the Board.

Now, in the discussion, the point seems to be missed that, while to-day a majority of those present, voting in favor of a thing, will carry, though they may not be a majority of the whole Board, this amendment provides that all the information—of course, that is in the Board itself, to give information to the members—the Board as a whole will have to vote on every name that is brought up, and three members of the Board will be sufficient to exclude, voting in the negative.

MR. GREENE.—I was quite aware of the blue list and of the manner of sending it out, but what I want to get at is, if there is anything in the Board of Direction, aside from what Mr. O'Rourke has just stated, that would enable the Board to decide this question any more accurately or justly than it is being decided in this, it seems to me, too loose way we have now. Is there any other?

MR. O'ROURKE.—They take whatever evidence they get. It is up to the members to furnish the Board with objections, and that is done all the time. It is a great mistake to think that every name that goes out on the blue list comes out on the white list afterward—it is far from that.

MR. GREENE.—It seems to me to be evident to every member of the Society that it is a very embarrassing thing, and a very difficult thing, for him to take a blue list, about which he may know something, or little, or much, or, perhaps, not anything, and he hesitates before he discriminates against a man and sends information to the Board, unless he has positive knowledge. It would not be fair for him to do it unless he had.

Now, it seems to me, the difficulty in this matter is that this thing is not concentrated in any workable, proper manner. It seems to me that there ought to be a committee of this Board of Direction whose business it shall be, confidentially, to ascertain the facts, and whose business it shall be to keep everything of that kind that they get into

Discussion on Amendment to the Constitution (Continued).

their possession positively and absolutely to themselves, and not as the gentleman over there has described, that he has known of cases where the Directors have given out information by which men were rejected, which is a very unjust thing, as we all agree.

Now, this matter of getting into this Society as a member should not be looked upon as so small a thing as not to attract anybody's attention. It is a great thing to be a member of this Society, if men would only look at it that way.

Now, what is our position in this matter? We are entrusted, more than any other body of men on this continent, with the expenditure of capital for the improvement of the public works of this country and the country's general good, and we are called upon, and should be held right up to the mark, that we make good that expectation of the public, because the man who takes a position as an engineer and disburses millions of money should be, beyond any question, rock-bound in his integrity, and naturally he should be well advised, well educated by experience, and show his ability to cope with the subjects that may come before him.

I make the statement here, and I believe it is true, that, for two reasons, more money has been wasted on the public works of this country in the last fifty years than it would take to pay the public debt of this country when our Civil War closed. What are those two reasons? They are very lucid, and very short, and very nubby. First, the brains and ability and knowledge of the business that the man who has the matter in hand, whether he is able to cope with it and do it properly, and the next is, whether he has got such integrity at rock-bottom that he will do justice between the parties, let what will come.

Now, we know that men have got into such positions in this country; for instance, this matter in Savannah, a few years ago, by a United States officer, educated, I believe, at West Point, and now serving time, in a western penitentiary, for stealing. There was a man, educated at his country's expense, and it seems to me the only mistake that was made in that man's case was that he had not gone to State's Prison before he went to West Point; then he could not have done this mischief.

There ought to be some way in which this Society can exact from the candidates who want to come into it facts and information sufficient to give the Board of Direction—or whoever is left to decide this question of who shall come in and who shall stay out—absolute knowledge enough so that they will feel that, conscientiously, they are safe in letting a man in, or they are acting exactly as honestly in saying that he cannot come in.

It seems to me, Mr. Chairman, that something of that kind should be done in the Board of Direction, if this amendment passes. Now, what is everybody's business is nobody's business, is an old saw—

older than any of us here—and if this amendment be passed, and the Board then appoints a sub-committee whose duty it shall be to do that, and make it their business to see to it, it seems to me that this question, and this trouble, will be largely removed, and very easily; but I do not see how it ever can be done, in the *modus* under which we are now proceeding.

Mr. Ricketts.—Mr. Chairman, I would like to ask a question. It is assumed that members of the Board of Direction who may reside in California are to vote intelligently on each application. Suppose a member shows a letter to the Board in which he says that he knows or believes that a certain applicant is a blackguard and a rascal, do I understand that, under this amendment, the Board intends to print that, and send it out through the United States mails to the different members of the Board throughout the United States? And, if they don't do that, how can the various members of the Board, distributed throughout the United States, vote intelligently in any case?

Mr. O'Rourke.—The best answer to that, Mr. Chairman, is to state what is the practice at present in the Board. All such communications, and all preliminary considerations of an applicant, are considered by a committee similar to the committee that Mr. Greene has spoken of, who take all these facts into consideration, and when the name comes before the Board they recommend either that he be accepted or rejected. Usually, the rejection follows in any case. I have never known of a name to go by that committee, so that, even if the Board was present, and even if they had this stuff piled up there in a basket before them, they would never even ask for it, or ask to see it, if the Committee's report on the man who is not favored by them is presented; I have never known of a case that it was not so considered by the action of the Board. There may be a few instances, of course, but I am probably proceeding too far; but I am talking about the general practice. The confidence of the Board in this Committee is so great that they rarely go beyond that, if there is any reason to believe that he is not worthy. No matter what would be the proceeding under this amendment, I would say that whenever any real occasion arose for communicating to everybody on the Board, means will be found to do it. I think we can trust the Board for that.

There is no doubt about it that the only way you can sift a thing like that is to sift it through a committee, and once your committee has given its conclusions on the matter, if you want to go behind the committee, then it is time to go about it.

Mr. Ricketts.—In other words, this local committee, which must necessarily be a local committee, is to determine who shall be members and who shall not be members of the Society. (Applause.)

E. P. North, M. Am. Soc. C. E.—Mr. President, I listened with a great deal of pleasure to Mr. O'Rourke's description of the proceedings before the Committee on Admissions. It does not quite agree with a

Discussion on Amendment to the Constitution (Continued).

little bit of experience I had, I think before Mr. Ricketts was a member of the Board.

I saw in the blue list the name of an applicant who, I thought, was unfit for membership. I wrote to the Board of Direction that, before his name was passed to ballot, I might be further communicated with, as I would like to make a personal communication. The next month the name came out on the ballot list. I inquired about the thing, and, while I cannot make any official statement, I think I am justified in mentioning my suspicion that the name was examined, one among over sixty, on a very hot September Tuesday, and the fact was that they did not get to my letter at all, but passed the man among that number, as I take it.

Now, that is an extreme case, I am perfectly willing to admit, and I wish to urge that it is an extreme case; but I wish to say to the members of this Society that if this proposed change in the Constitution is made, one provision against the admission of unworthy members is swept away. It does not make much difference to the older men in the profession what reputation a young man has, but a young man who is looking for a place, and says he is a member of the American Society of Civil Engineers, is very severely handicapped by the knowledge that another member of the Society is unworthy of the name, either of a civil engineer or a man. (Applause.)

G. F. Swain, M. Am. Soc. C. E.—Mr. Chairman, I am heartily in favor of Mr. O'Rourke's amendment. I hope it will be adopted. I believe in concentrating responsibility, and I do not know of any better place to concentrate responsibility than upon the Board of Direction of this Society. It is the way that every large corporation does business; it is the way that a great many of the large clubs, if not all of them, and many of the professional societies elect members.

I think that we might trust the Society, as Professor Allen suggests, if the Society had information, and if the Society, and every member of the Society, or every seven members of the Society, would act squarely. I do not believe in giving seven members of the Society an opportunity to stab a man in the back for personal reasons. If there are seven members of the Society who think that a man ought not to be admitted, they certainly can bring information enough into the possession of the Board of Direction to enable that Board to form a fair opinion of the justice of their reasons.

I think that it must not be lost sight of that the proposed amendment will change the present mode of procedure of the Board, Five members of the Board now constitute a quorum, I believe, and three, therefore, would enable a meeting of the Board to pass a candidate for ballot. That is the way in which, perhaps, some unworthy men have become elected, have been passed to ballot, as Professor Allen states.

The mode of procedure proposed by Mr. O'Rourke would require the Board of Direction to vote by letter-ballot. I do not see that there is any difficulty, as Mr. Ricketts seems to think, in getting information to the various members of the Board in regard to the unworthiness of certain candidates. If a member of this Society knows that a candidate is a blackguard, and writes to the Board, giving his information, it is just as easy to write to the various members of the Board and give them the facts. There is no difficulty about that.

Ibelieve in concentrating responsibility in the Board, and I think very likely the Board would modify, to some extent, its procedure. Responsibility always makes a man more careful. The Board is very careful now; I know from experience how much care is taken by the Board on the admission of candidates, and how carefully they consider every candidate. I cannot conceive at the present time of any letter from Mr. North not having been given great consideration. I don't know how it was. It was many years ago, perhaps ; but I know how it is at present, and I, therefore, am strongly in favor of the amendment of Mr. O'Rourke. (Applause.)

Mr. North.—I would like to ask, before the Professor sits down, definitely, if it is much better to allow three or five men to stab a man in the back than seven ? It really comes to the Board of Direction, a smaller number of Directors than is required now, preventing absolutely a man's election. The Directors are taken from the main body of the Society, and I do not understand that they are much more reliable than those of us who are not Directors, and are fully as able to stab a man, I take it (laughter).

Mr. Green.—It is a great deal safer for the Society to reject a good man this year, if he can be admitted later, when more information about him can be secured than could be had in the first place, than it is to let an unqualified man come in. If there is anything at all of value to the members, or anything at all in membership in the Society, it should be the standing of its members as good engineers, and if an unworthy, unqualified man gets in, he is in there to stick, and you cannot get him out, but you can very easily put in a qualified man who has been passed over the first year for lack of information, or because someone wishes to stab him in the back, and elect him after a while.

I think the Board of Direction can be entirely trusted in this business, and if five members, only, constitute a quorum before the letter-ballot was sent out to all the members to vote upon the candidate, and it happens to be found that three out of those five vote against him on the spot because there is some question about the candidate, it is not necessary to send out the ballots to all the membership. It seems to me that we are straining at a gnat and swallowing a camel. Mr. Rickett's case has been entirely taken care of and disposed of in

Discussion on Amendment to the Constitution (Continued).

the particular way that it came up, if the minority who may have voted against the candidate at that time had been three in number.

I believe, as do many others, in holding up to a very high standard the candidates for membership in the Society. I think that too many men get in now who are lacking in the qualifications that they ought to have; they might wait a little while. A good many young fellows on reaching the age of thirty apply for membership and try to get in, but it is better for the Society that the Board of Direction should scrutinize these applications with considerable care, and, in my experience, it is safer for them to reject them, if necessary; and I say that it is a great deal better for the Society to reject, once in a while, a very well qualified man, a desirable man, than it is to make a mistake and elect an unqualified man.

(The President resumed the chair.)

T. S. White, M. Am. Soc. C. E.—I would like to ask the President one question in regard to the amendment that he spoke of and suggested a little while ago, as to increasing the number necessary to exclude. Have there ever been twenty negative votes cast against any member?

G. I. Bailey, M. Am. Soc. C. E.—Mr. President, in regard to this amendment to the amendment proposed by Mr. O'Rourke, I wish to say that I am opposed to it, and that several members of this Society, who do not live in New York, and whose associations in the Society are confined to receiving its publications, and the communications mailed from the Secretary's office, and an occasional blue list and ballots to members, are opposed to it.

If abuses have been made in the election of members to this Society, I think the thing to do is to get at those abuses and stop them. If you cannot expect the members to vote intelligently and properly for admittance of candidates to their own membership, I do not see how you can cure that evil by allowing those same members to vote for members of the Board of Direction, and then shifting that responsibility over to that Board.

I believe the suggestion made by yourself, or by some one before, that if a committee of seven in the Society may keep out members, then that number should be enlarged, and, as you say, a percentage of the whole membership of the Society, or else a percentage of the whole number of votes cast, should exclude. The pink ballot does correct that evil of seven, as has been demonstrated a number of times in the last few years, but for these up-country members, of whom I am one, we like to have something to say, occasionally, in regard to the Society, and feel perhaps like the Americans of a hundred and thirty years ago, when they had the little tea-party up around Boston. We are all taxed for the Society, we pay our dues, and we want something to say for it, and if we are not competent to pass upon our own members, I

do not believe in appointing some nurse to do it for us; give us all a chance. (Cries of Question.)

THE PRESIDENT.—The question is called for. The question is upon the amendment to the amendment offered by Mr. O'Rourke, which, I think, it is not necessary to read. Those who are in favor of the adoption of the amendment to the amendment proposed by Mr. O'Rourke will signify by saying aye; contrary, no.

The Chair is unable to decide.

G. S. MORISON, Past-President, Am. Soc. C. E.—Before any further vote is taken, Mr. President, I should like to know what this amendment to the amendment is?

THE PRESIDENT.—Well, it is an amendment which, in effect, throws the election of members wholly into the Board of Direction.

MR. MORISON.—May I ask to have that read?

THE PRESIDENT.—The reading of that amendment is asked for, and I will ask the Secretary to read it.

(The Secretary read the amendment to the amendment.)

THE PRESIDENT.—Having heard the amendment to the amendment, proposed by Mr. O'Rourke, all those who are in favor of it will signify by rising and standing until counted.

(The Secretary announced sixty-eight votes.)

MR. ALLEN.—I rise to a point of order. I would like to know what the situation is as to those men who are standing, not from their seats, but behind the seats in the rear of the room; are those members properly counted in the room or not?

THE SECRETARY.—I counted everybody standing in the room; not outside of the room.

THE PRESIDENT.—Those who are opposed to the amendment will rise.

(The Secretary announced eighty-eight votes.)

THE PRESIDENT.—The amendment is lost. The question now recurs upon the amendment as it was heretofore read, the amendment which you have received in print.

THE SECRETARY.—Allow me to say, Mr. President, that this meeting can do nothing with that amendment except to amend it. Unless that proposed amendment is amended by this meeting, under the Constitution, it goes to letter-ballot of the Society.

THE PRESIDENT.—The Secretary is correct. The proposed amendment having failed, the original amendment goes to the Society for letter-ballot. If there is no amendment offered to this, it will go out in the form in which it is. This is simply to the effect that the Board of Direction may classify; it has no bearing upon the number of negative votes that may be necessary to exclude.

MR. KNAP.—I wish to ask for information, now that that amendment has been voted down, is it in order to present another amendment?

Discussion on Amendment to the Constitution (Continued).

THE PRESIDENT.—In the nature of an amendment to this; yes, sir.

MR. KNAP.—I am sorry I have not got it written down, but I would like to make an amendment to the amendment to this effect, that, in order to exclude, the number of negative votes should be 1% of the Corporate Membership at the last Annual Meeting, or at the time of the last Annual Report; 1%, which would be, as the President has stated before, about twenty at the present time. Instead of seven, I wish to substitute the number twenty.

THE PRESIDENT.—That is, you wish to substitute 1 per cent.

MR. KNAP.—Twenty, or 1%, which will be at this time about twenty.

MR. SWAIN.—I second the motion.

THE PRESIDENT.—The amendment is seconded and is now before you, which amends Section 4 of Article III, making it 1% of the Corporate Membership.

THE SECRETARY.—As of the 1st of January of each year?

THE PRESIDENT.—Yes; necessary to exclude.

MR. KNAP.—I would state, in addition to that, that when the number seven was decided upon, as I understand it, there were about seven hundred members in the Society, and that was really about 1%, but twenty is now practically the same percentage of the Society as seven was at that time.

THE PRESIDENT.—The amendment is now before you for discussion, gentlemen.

ALLEN HAZEN, M. Am. Soc. C. E.—It seems to me that there may be a great many men proposed for membership of whom there would not be twenty men who know well enough about their position and standing to pass intelligently upon this point, and in that respect twenty to-day may be a much more liberal allowance than seven, which was 1% at the time it was adopted, if that were the case. And I question if twenty is not a larger number than we can afford to give at the present time, even if seven is too small. I am not one of those who feel that to be defeated by seven votes is anything to be ashamed of, or to feel unduly. There is a satisfaction in having gone through the pink ballot and feeling that the great majority of the members of the Society are behind you.

MR. WHITE.—Just in regard to that point that Mr. Hazen has made, the question arises again as to how many votes were ever cast against a man, and whether it is possible that anybody would ever be excluded if it required twenty votes to exclude him as a member.

THE SECRETARY.—There have been twenty votes cast against a candidate, and there has also been one voter who has voted against all the candidates on a ballot list, on which I think there were forty-six.

MR. HILL.—As I understand it, Mr. President, 1% of the Corporate Membership, according to the list as handed out to-day, is only about

seventeen voters, and seventeen votes are considerably less than twenty. It seems to me that the real effect of this proposed amendment is to carry into effect by indirection the amendment which has just been voted down, because it seems to me that it would rarely happen that such a number of adverse votes would be cast. It seems to me that that is a very exceptional number. In this particular case the men who know objectionable characteristics on the part of the candidate, in order to make that objection effective, must vote through the Board of Direction, so that the effect will be, if we feel that a candidate is objectionable, we must go to the Board and stop him there, feeling certain that it will be difficult to get the requisite number of voters.

(Calls for the question.)

F. W. Hodgdon, M. Am. Soc. C. E.—Mr. Chairman, this question seems to be entirely out of order. The question of the number of negative votes which will come up is an entirely new question. It is not an amendment to the amendment which is to go before the Society at the present time. That simply refers to the application of the applicant. This is the method of election of the applicant, and should come in as an entirely new amendment and be presented to the meeting, and be presented to the Society for discussion. (Applause.)

(Calls for the question.)

Mr. Croes.—I think, Mr. President, that this is entirely germane to the amendment. This resolution making the change in the Constitution is offered, and this changes two or three words of it, and that is all.

Mr. Hodgdon.—Not germane to the subject, but to the other amendment.

Mr. Croes.—It changes two or three words in that; it makes it twenty instead of seven, that is all.

Mr. Hodgdon.—That question is not up in the amendment.

Mr. Croes.—The amendment is this amendment to the Constitution, and this is an amendment to that amendment, and it is perfectly proper.

(Calls for the Question.)

The President.—That raises a question which it is a little difficult for me to decide off-hand. Both are amendments to Article III, though not to the same section of Article III.

The Secretary.—The language of the Constitution is, that an amendment may be amended in any manner pertinent to the original amendment.

Mr. Hodgdon.—What section is it that it is proposed to be amended?

The President.—It is proposed in the original to amend Section 3, Article III.

Discussion on Amendment to the Constitution (Continued).

MR. HODGDON.—In relation to the proposed amendment to that, where we had the proposed amendment of Mr. O'Rourke, that came up, because it was proposed to amend Sections 2 and 3 of Article III; but the amendment proposed by Mr. Knap amends Section 4 of Article III. I just raise the point of order that it is not germane.

THE PRESIDENT.—I think I shall have to decide that it is not in order.

Resolution in reference to the late Abram S. Hewitt.

MR. MORISON.— Mr. President, is there any other business to come immediately before the meeting? If not, I would like to offer a resolution. It has not been the custom of this Society to pass special resolutions in relation to special men, but it seems to me that the coincidence of this meeting in connection with the history of this city, and of the country, for a great many years, calls for some special action now.

Some of us were late in coming to this meeting to-day, and the reason for that was because we cared more about rendering the little respect we could to one whose memory the whole engineering profession has honored than for attending to the business here this morning, important though it be.

At precisely the same hour for which this meeting was called the last services were held over the man who, for a long time, we have looked upon as New York's first citizen, and who, if any man outside of the profession has ever done much for engineers, he has certainly done it. My own personal acquaintance with him began about thirty years ago, and for twenty years I have felt that, if there was any subject upon which I needed especially sound advice and help, he was the man for me to go to. I think there are many of us who have felt in that same way.

I therefore offer the following resolution:

Resolved, That the members of the American Society of Civil Engineers, assembled in their Annual Meeting at the hour when the last sacred rites were performed over the mortal remains of Abram S. Hewitt, desire to place on record a brief recognition of the debt which so many of them individually, and all of them as a profession, owe to him who was for so many years New York's first citizen.

While he always disclaimed being an engineer, he had the mind and spirit which mean more than the actual professional name. While not enrolled among their numbers, his whole life, as a citizen, a manufacturer and an educator, was devoted to those interests which have made the engineering profession possible.

Few cities have had so patriotic a citizen. No profession has had a warmer friend.

(Applause.)

R. W. HUNT, M. Am. Soc. C. E.—I desire the privilege of being a seconder to that resolution, and I think, sir, we all feel it fitting that this Society should pass such a resolution. While Mr. Hewitt was not a member of our own organization, he was a Past-President of a sister

national society, and, surely, if ever a man served his country, and served his country in a way that was effective, it was he.

In looking at the progress of the world, the advancement of mankind, and those who have been connected with it, it is difficult to draw lines showing exactly where such a one's influence has extended and ended.

So, with Abram S. Hewitt, we cannot exactly mark out the great industrial advancement of the United States, or the progress, or the better condition of its citizens that was brought up to a certain point by him; but surely no man has lived in his generation who has done more to sweep on that tide. He has given and done the things that were best calculated for the true advancement and the true benefit of his fellow men, and now, sir, God has made the just man perfect. (Applause.)

THE PRESIDENT.—Gentlemen, you have heard the resolution offered by Mr. Morison, and so ably seconded by Mr. Hunt. All in favor of its adoption will signify by rising.

It is a unanimous vote.

THE SECRETARY.—I have the report of the tellers.

THE PRESIDENT.—If there are no other resolutions to offer——

J. A. OCKERSON, M. Am. Soc. C. E.—I would like to offer a resolution.

THE PRESIDENT.—Well, that will be in order.

International Congress of Engineering.

MR. OCKERSON.—*Resolved*, That it is the sense of this meeting that the American Society of Civil Engineers should co-operate with the officers of the Louisiana Purchase Exposition Company, in the inauguration of an International Congress of Engineering, to be held in St. Louis, during the Exposition period of 1904, and be it further

Resolved, That the Board of Direction be, and is, hereby, authorized and requested to take such steps as may be necessary to carry out the provisions of the foregoing resolution.

I might say, gentlemen, in this connection, that the Exposition Company is making very generous provisions for the scientific congresses, and, of course, it is important that the American Society of Civil Engineers should take a leading part in the engineering congresses. For my own part, I should be very glad to have the Society make use of my department at the Exposition in any way possible to help this matter along. The use of stenographers, typewriters, and other members of the force is at your service.

The resolution was duly seconded.

THE PRESIDENT.—Is there any further discussion upon it? I will ask for the vote. Those in favor of the adoption of the resolution, which you have just heard read, will signify by saying aye; those opposed no.

Carried.

THE PRESIDENT.—If there are no further resolutions, the next order of business will be the report of the tellers.

Report of Tellers.

THE SECRETARY. The tellers' report is as follows:

Report of Tellers Appointed to Canvass the Ballot for the Election of Officers at the Annual Meeting, January 21st, 1903.

Mr. Chairman: Your Committee, appointed to canvass the ballot for Officers, reports as follows:

Total number of ballots received		710
Not entitled to vote	1	
Without signature	13	
Voted nominating blank	1	
	—	15
Counted and found correct		695

For President:

Alfred Noble	691
Edward A. Bond	1
F. W. Cappelen	1
Henry S. Haines	1

For Vice-Presidents:

L. F. G. Bouscaren	684
James D. Schuyler	687
O. F. Nichols	2
Wm. M. Black	1
Addison M. Scott	1
Howard G. Kelley	1
Thomas H. Johnson	1
D. C. Henny	1
W. H. Kennedy	1
W. F. Tye	1

For Treasurer:

Joseph M. Knap	693
Palmer C. Ricketts	1

For Directors:

Alfred Craven	686
Joseph O. Osgood	684
George S. Davison	676
E. C. Lewis	672
Hunter McDonald	679
Elwood Mead	671
C. E. Grunsky	3
J. M. Johnson	2
J. B. Lippincott	2
H. M. Wilson	2

David E. McComb	1
R. C. McCalla	1
Chas. H. Graham	1
B. S. Wathen	1
A. M. Scott	1
J. C. Guild	1
J. A. Ockerson	1
Jos. Ramsey, Jr.	1
Geo. S. Webster	1
Arthur L. Adams	1
D. C. Henny	1
W. H. Kennedy	1
Edward B. Taylor	1
Louis Y. Schermerhorn	1
F. A. Molitor	1
C. L. Harrison	1
D. W. Lum	1
James B. Atkinson	1

GEO. C. STODDARD,
C. D. POLLOCK,
Tellers.

JANUARY 21ST, 1903.

Remarks by Past-President Moore.

THE PRESIDENT.—Gentlemen, you have heard the report of the tellers, and with this election your present President retires. I cannot do so, however, without expressing to you and to the Society at large my thanks for the compliment which you have paid me in choosing me as your President, and further extending my congratulations to the Society upon the great prosperity which this Fiftieth Anniversary Meeting now witnesses; and when we see what we do see here before us, a large Society gathered in a house of its own, and compare it with the small beginning of the Society fifty years ago, I think we see that there has been planted here a very vigorous plant, and we may be sure that the next fifty years will witness a Society which will be of the utmost importance, not only to this profession, but to the whole country.

President Noble Introduced.

I will ask Mr. Morison and Mr. Croes to conduct the new President to the Chair.

ALFRED NOBLE, President, Am. Soc. C. E.—Gentlemen of the American Society of Civil Engineers: I appreciate very deeply the honor of the election to the Presidency of this Society, and this cordial greeting which you have been good enough to accord me. This Society is the best exponent of the profession of engineering on this hemisphere. Of the four great national societies, it is the one which seeks to embrace in its ranks all branches. Nine times in ten the engineer

must stand or fall on the simple issue of the performance of duty. On this issue, I perceive, with some alarm, that I must hazard what I prize most highly, the continuance of the good opinion of my professional brethren. In return for the honor which you have been good enough to bestow on me, I can only promise to regard the responsibilities I am about to assume as commensurate with the honor they imply, and to discharge the duties which I gratefully assume to the best of my power. (Applause.)

Memorial Tree at Mount Vernon.

THE SECRETARY.—Mr. President, I have one letter which I omitted to read, and with your permission I will read it now.

ST. LOUIS, MO., JAN. 19, 1903.

MR. CHARLES WARREN HUNT,
Sec'y. Am. Soc. Civ. Engineers,
New York.

Dear Sir:

I hereby report to the Society that, in pursuance of the resolution passed at the last Annual Convention in Washington, I have had an oak tree planted at Mount Vernon, as a memorial of the visit of the Society in May last.

In the execution of this work, I have had the invaluable assistance of Mr. Gifford Pinchot and Mr. George B. Sudworth of the Bureau of of Forestry and Mr. Harrison H. Dodge, Superintendent of the Mount Vernon Estate, and the thanks of the Society are due to these gentlemen.

Yours very truly,

ROBT. MOORE,
President.

MR. MOORE.—I move that the Secretary be instructed by this meeting to extend the thanks of the Society to these gentlemen whom I have named. They have executed, with great skill and fidelity, this commission which was placed on them, and, I may say, without any cost to the Society. I think that the vote of thanks is due to them.

The motion was duly seconded and carried.

After several announcements by the Secretary as to features of the programme for the meeting, the meeting, on motion duly seconded, was adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE FIFTIETH ANNUAL MEETING.

Wednesday, January 21st, 1903.—After the business meeting, lunch for about 450 members was served at 1.30 P. M. in the Lounging Room. At 3 P. M. a large party, under the guidance of Alfred Craven, M. Am. Soc. C. E., Division Engineer, visited and inspected the tunnel of the Rapid Transit Railroad, between Sixtieth and Forty-second Streets. The station at Broadway and Sixtieth Street, and various portions of the tunnel were lighted for the occasion. Smaller parties visited other parts of the work, in Harlem, on Park Avenue, at the City Hall, etc., during the afternoon.

At 9 P. M. there was a Reception, with dancing, in the Society House, at which the total attendance was about 375.

Thursday, January 22d, 1903.—At 10 A. M. the steamer *Valley Girl* (kindly furnished for the occasion by John H. Starin, Esq., and General Howard Carroll) with about 400 members and guests, including many ladies, left the Recreation Pier at the foot of East Twenty-fourth Street for an excursion. By invitation of Hon. Gustav Lindenthal, M. Am. Soc. C. E., Commissioner of Bridges, the party visited the site of the Blackwell's Island Bridge (No. 4) and inspected the masonry piers, on Blackwell's Island and at Ravenswood, in course of construction. Lunch was served on the boat while on its way down the river, and a stop was made at Hoboken to inspect the new fireproof piers which are being constructed by the North German Lloyds Steamship Company. The party was landed at the pier at the foot of West Thirty-fifth Street, New York, at about 5 P. M.

In the evening there was an informal "Smoker" at the Society House, about 400 members and guests being in attendance.

The following list contains the names of 396 members, of various grades, who registered as being in attendance at the Annual Meeting. This list is incomplete, on account of the failure of many members to register, and it does not include the names of any of the guests, of the Society or of individual members:

Abbot, F. W.....New York City
Abbott, E. L.....New York City
Aiken, W. A.....Pittsburg, Pa.
Allen, C. A.....Worcester, Mass.
Allen, W. A.....Maurer, N. J.
Ashbridge, R. I. D. Philadelphia, Pa.
Atkins, H. B.....New York City
Auryansen, F.....New York City
Aus, G.....New York City
Bacon, J. W.....Danbury, Conn.
Bailey, G. I.....New York City
Baker, E. B. Morgantown, W. Va.
Barnes, W. T.....Boston, Mass.
Bascom, H. F..... Allentown, Pa.
Basinger, J. G.....New York City
Belden, E. T. Middletown, Conn.
Belknap, W. E....New York City
Bellinger, L. F...Brooklyn, N. Y.
Belzner, T.....New York City

Bensel, J. A.....New York City
Benton, L. S.....New York City
Benzenberg, G. H. Milwaukee, Wis.
Berg, W. G.....New York City
Bettes, C. R. Far Rockaway, N. Y.
Beugler, E. J.....Boston, Mass
Bishop, G. H. Middletown, Conn.
Bissell, C. T.....New York City
Bissell, H.....Boston, Mass.
Boller, A. P.....New York City
Boller, A. P., Jr....New York City
Bonzano, A.....Philadelphia, Pa.
Booth, W. F.....New York City
Bouscaren, G....Cincinnati, Ohio
Bowman, A. L.....New York City
Bramwell, G. W...New York City
Breuchaud, J.....New York City
Brinckerhoff, H. W. New York City
Bryson, A.....Reading, Pa.
Buchholz, C. W....New York City
Buck, H. R.....Hartford, Conn.
Buck, L. L.....New York City
Buck, R. S.....Montreal, Canada
Burdett, F. A.....New York City
Bush, E. W.....Hartford, Conn.
Butts, E. P....Springfield, Mass.

Carney, E. J.....New York City
Carr, A.....New York City
Carter, A. E .....New York City
Carter, Shirley.....Norfolk, Va.
Cattell, W. A.....New York City
Chambers, R. H....New York City
Chase, F. L.....New York City
Chester, J. N.....Pittsburg, Pa.
Christian, G. L....New York City
Christie, G. B.....Chicago, Ill.
Clapp, O. F.....Providence, R. I.
Clark, G. H.....New York City
Clark, J. A., Jr. East Orange, N. J.
Clark, L. V.....Philadelphia, Pa.
Clarke, St. John....Bogota, N. J.
Codwise, E. B....Kingston, N. Y.
Cogswell, W. B...Syracuse, N. Y.
Colby, S. K.....New York City
Collier, B. C.....New York City
Collingwood, F..Elizabeth, N. J.
Conrow, H.....New York City
Cook, J. H.....Paterson, N. J.
Cooper, S. L.....Yonkers, N. Y.
Cooper, T.....New York City
Copeland, W. R. Philadelphia, Pa.
Cornell, J. N. H...New York City
Corthell, A. B....New York City
Coverdale, W. H..New York City
Crane, C. A.....New York City
Crane, F. E....Amsterdam, N. Y.
Craven, A.....New York City
Crehore, W. W....New York City
Creuzbaur, R. W..New York City
Croes, J. J. R.....New York City
Crowell, F.....New York City
Cuddeback, A. W. Paterson, N. J.
Cudworth, F. G...New York City

Davies, J. V.....New York City
Davis, A. L.....New York City
Davis, Chas.....Allegheny, Pa.
Davis, R. B.....Boston, Mass.
Davison, G. S.....Pittsburg, Pa.
Dawley, E. P...Providence, R. I.
Dean, L.....Taunton, Mass.
Deans, C. H.....New York City
Deans, J. S.....Phœnixville, Pa.
Devin, G.....New York City
De Witt, P. H.....New York City
Diebitsch, E.....New York City
Dorrance, W. T...New York City
Dunham, H. F....New York City

Easby, M. W...Philadelphia, Pa.
Ehle, B.....East Creek, N. Y.
Ellis, J. W....Woonsocket, R. I.
Erlandsen, O.....New York City
Evans, J. M.....Brooklyn, N. Y.
Evans, L. H.....New York City

Fernstrom, H.....New York City
Fisher, C.....Trenton, N. J.
Fisher, E. A.....Rochester, N. Y.

Fitch, C. L.....Brooklyn, N. Y.
Francis, G. B.....New York City
Francis, H. N...Providence, R. I.
Frazee, J. H.....New York City
French, A. H....Brookline, Mass.
French, A. W...Worcester, Mass.
French, J. B.....New York City
Frost, G. S.....New York City
Fuller, A. D.....Boston, Mass.
Fuller, F. L.....Boston, Mass.
Fuller, G. W.....New York City
Fuller, W. B.....New York City

Gartensteig, C.....New York City
Gifford, G. E .... New York City
Gillespie, R. H....New York City
Goad, C. E ....Montreal, Canada
Goodnough, X. H..Boston, Mass.
Gould, E. S.....Yonkers, N. Y.
Gowen, C. S .... Ossining, N. Y.
Graham, C. H.....New York City
Grant, T. H.....Red Bank, N. J.
Green, B. R...Washington, D. C.
Greene, F. S.....New York City
Greene, J. N.....Boston, Mass.
Gregory, C. E.....New York City
Gregory, J. H....Paterson, N. J.
Grimm, C. R.....New York City

Hagar, E. M.....Chicago, Ill.
Haight, S. S .....New York City
Hall, M. W.....New York City
Hammatt, W. C..Mexico, Mexico
Hammer, R. H.....New York City
Harlow, J. H..... Pittsburg, Pa.
Harper, A. C .....New York City
Harrington, J. L..New York City
Harris, C. M.....New York City
Harrison, E. W.,
Jersey City, N. J.
Harwi, S. J.....Bayonne, N. J.
Harwood, G. A...Syracuse, N. Y.
Hatt, W. K....Washington, D. C.
Hatton, T. C...Wilmington, Del.
Hauck, W.....New York City
Haviland, A.....New York City
Hayes, E.....Cohoes, N. Y.
Hayes, S. W.....Geneva, N. Y.
Hazelton, C. W.,
Turner's Falls, Mass.
Hazen, A.....New York City
Hemming, D. W..New York City
Hendrick, C. W...New York City
Herbert, H. M.,
Bound Brook, N. J.
Hering, R.....New York City
Herschel, C.....New York City
Hickok, H. A.....Newark, N. J.
Hill, G.....New York City
Hoag, S. W., Jr....New York City
Hodgdon, F. W....Boston, Mass.
Hoffman, N. B. K..New York City
Holliday, A. R....Newcastle, Pa.
Hone, F. de P.....New York City
How, R. W.....New York City
Howe, E. W.....Boston, Mass.
Hudson, C. W...Phœnixville, Pa.
Humphrey, R. L.,
Philadelphia, Pa.
Hunt, Charles Warren,
New York City
Hutchings, W. E.,
Louisville, Ky.

Irving, W. E.....New York City

Jacoby, H. S.....Ithaca, N. Y.
Jackson, W.....Boston, Mass.
Jaques, W. H.....Boston, Mass.
Jarrett, E. S.....New York City
Johnson, A.....New York City
Johnson, A. L.....St. Louis, Mo.
Johnson, L. J..Cambridge, Mass.
Johnson, W. S.....Boston, Mass.
Just, G. A.....New York City

Kaufman, G.....Brooklyn, N. Y.
Kelly, C. W. ..New Haven, Conn.
Kelly, O. M.....New York City
Kenney, E. F...Philadelphia, Pa.

Khuen, R., Jr.....Pittsburg, Pa.
Kimball, G. A.....Boston, Mass.
King, P. S.....New York City
King, W., Jr.....New York City
Knap, E. D.....New York City
Knap, J. M.....New York City
Knapp, L. H.....Buffalo, N. Y.
Knight, F. B.....New York City
Knowles, M.....Pittsburg, Pa.

La Chicotte, H. A..New York City
Lamb, R.....New York City
Landreth, W. B....Albany, N. Y.
Latta, H. W....Philadelphia, Pa.
Lederle, G. A.....Chicago, Ill.
Lee, D. R.....Middletown, N. Y.
Lee, W. B.....Hillburn, N. Y.
Leffingwell, F. D..Harrisburg, Pa.
Leisen, T. A ...Wilmington, Del.
Leonard, H. R..Philadelphia, Pa.
Lesley, R. W...Philadelphia, Pa.
Lewis, F. H.....Craigsville, Va.
Lewis, M. H.....New York City
Lewis, N. P.....New York City
Lindenthal, G....New York City
Lofland, H. F.....Pencoyd, Pa.
Loomis, H.....New York City
Low, G. E.....New York City
Lowinson, O.....New York City
Ludwig, J. A.....New York City
Lund, G. A....Bridgeport, Conn.
Lundie, J.....New York City
Luster, W. H., Jr.Elizabeth, N. J.

Macdonald, A. A..New York City
Macdonald, C.....New York City
MacGregor, R. A..New York City
Machen, H. B.....New York City
Maclay, W. W.....New York City
McComb, C. O..Watertown, N. Y.
McDonald, H. P., Jr.,
Jersey City, N. J.
McHarg, L.....New York City
McKenzie, T. H.,
Southington, Conn.
McMinn, T. J.....New York City
McNicol, J. A.....New York City
McNulty, G. W...New York City
Malukoff, A. J....New York City
Manley, H.....Boston, Mass.
Marden, H. H., Jr..New York City
Marple, W. M.....Scranton, Pa.
Martin, C. C.....Brooklyn, N. Y.
Martin, W.....New York City
Mason, F.....New York City
Mead, C. A.,
Upper Montclair, N. J.
Mead, E.....Washington, D. C.
Meem, J. C.....New York City
Merriman, M.....Bethlehem, Pa.
Merriman, T.....New York City
Merryman, W. C..New York City
Metcalf, L.....Boston, Mass.
Miller, H. A.....Clinton, Mass.
Miller, H. C.....New York City
Miller, R. P .....New York City
Moisseiff, L. S.....New York City
Moore, C. H.....New York City
Moore, W. H..New Haven, Conn.
Morse, C. A.....La Junta, Colo.
Moulton, M....Springfield, Mass.
Myers, C. H.....New York City
Myers, J. H.....New York City

Neumeyer, R. E..Bethlehem, Pa.
Nichols, C. H..New Haven, Conn.
Nichols, O. F.....Brooklyn, N. Y.
Noble, A.....New York City
North, E. P.....New York City

O'Brien, J. H.....New York City
Ockerson, J. A....St. Louis, Mo.
Odell, F. S...Port Chester, N. Y.
Olney, L. F.....New York City
O'Rourke, J. F....New York City
Orr, A.....Gloversville, N. Y.
Osborn, F. C....Cleveland, Ohio
Owen, J.....Newark, N. J.
Oxholm, T. S.,
West New Brighton, N. Y.

Parker, A. McC...New York City
Parker, C. J.....Rutland, Vt.
Parsons, W. B....New York City
Pegram, G. H.....New York City
Pitts, T. D.....New York City
Plimpton, A. L....Boston, Mass.
Pollock, C. D....Brooklyn, N. Y.
Potter, H. W.....New York City
Pratt, W. A.....New York City
Pratt, W. A....Philadelphia, Pa.
Price, P. W.....Pittsburg, Pa.
Prout, H. G.....New York City

Quimby, H. H..Philadelphia, Pa.

Rafter, G. W....Rochester, N. Y.
Ramsey, E. P.....New York City
Raymond, W. G.....Troy, N. Y.
Reed, D. A.....Duluth, Minn.
Reed, W. B.....New York City
Reid, H. A.....Brooklyn, N. Y.
Reynders, J. V. W.,
Harrisburg, Pa.
Rice, G. S.....New York City
Richardson, C....New York City
Richardson, C. L.Montclair, N. J.
Ricketts, P. C.....Troy, N. Y.
Ridgway, R.....New York City
Riedel, A. E.....Montclair, N. J.
Rogge, J. C. L....New York City
Rosenberg, F....Montclair, N. J.
Russell, R. L....Brooklyn, N. Y.
Ryan, M. H.....New York City

Scarborough, F. W.,
Richmond, Va.
Schmitz, F. C.....New York City
Schneider, C. C.Philadelphia, Pa.
Sherrerd, M. R....Newark, N. J.
Shryock, J. G..Philadelphia, Pa.
Simpson, G.....New York City
Simpson, G. F....New York City
Sinclair, F. O....Burlington, Vt.
Skinner, F. W.....New York City
Smith, A.....New York City
Smith, C. W.....New York City
Smith, J. W.....New York City
Smith, W. F.....New York City
Snow, J. P.....Boston, Mass.
Sooysmith, C.....New York City
Spencer, W. T.New Haven, Conn.
Sperry, H. M.....New York City
Spooner, A. N.....New York City
Stearns, F. L.....New York City
Stearns, F. P.....Boston, Mass.
Steffens, W. F....New York City
Stern, E. W.....New York City
Stevens, A .....New York City
Stewart, J. H.....New York City
Stewart, J. M.....New York City
Stoddard, G. C...New York City
Strachan, J.....Brooklyn, N. Y.
Strawn, T. C.....Newark, N. J.
Strobel, C. L.....Chicago, Ill.
Swain, G. F.....Boston, Mass.
Swensson, E....Pittsburg, Mass.
Swinburne, G. W..New York City
Swindells, J. S..Mt. Kisco, N. Y.

Tainter, F. S.....Far Hills, N. J.
Taylor, C. F...East Boston, Mass.
Taylor, L. A.....Boston, Mass.
Temple, J. C...Philadelphia, Pa.
Temple, W. H. G.Providence, R. I.
Tenney, G. O.Spartanburg, S. C.
Thackray, G. E...Johnstown, Pa.
Thomas, G. E.....New York City
Thomes, E. H.....New York City
Thomson, G. H...New York City
Thomson, T. K...New York City
Thornley, J.....New York City
Tibbals, G. A....Brooklyn, N. Y.
Tibbals, S. G....Brooklyn, N. Y.
Tighe, J. L.....Holyoke, Mass.
Tilden, C. J.....New York City
Tingley, R. H...Providence, R. I.
Travell, W. B.
West New Brighton, N. Y.
Tribus, L. L.....New York City
Triest, W. G. F...New York City

Trotter, A. W.....New York City
Trout, C. E.....New York City
Tucker, L. W.....Albany, N. Y.
Turner, D. L.....New York City
Turner, E. K.....Boston, Mass.
Turrill, S. M.....Syracuse, N. Y.
Tuttle, A. S.....New York City

Ulrich, D.....New York City
Upham, R. D.....New York City

Value, B. R.....New York City
Van Horne, J. G..New York City
Vier, H.....New York City
Vogleson, J. A. Philadelphia, Pa.
Vredenburgh, W., Jr.
New York City
Vrooman, M..Gloversville, N. Y.

Wadsworth, J. E..New York City
Wagner, S. T...Philadelphia, Pa.
Ward, C. D.....New York City
Ward, C. R.....New York City
Ware, R. W.....Plainfield, N. J.
Washington, W. de H.,
New York City
Watkins, F. W....New York City
Webster, A. L.....New York City
Webster, G. S..Philadelphia, Pa.
Webster, W. R.Philadelphia, Pa.
Weiskopf, S. C....New York City
Weston, R. S.....Boston, Mass.
Wheeler, H. R....New York City
Wheeler, R. N....New York City
Whiskeman, J. P..New York City
White, L.....New York City
White, T. S.....Beaver Falls, Pa.
White, W. U ..Philadelphia, Pa.
Whitson, A. M....New York City
Wiggin, E. W.New Haven, Conn.
Wiggin, T. H.....Boston, Mass.
Wiggins, W. D.....Toledo, Ohio
Wilcock, F. .....New York City
Wilgus, W. J.....New York City
Wilkes, J. K.New Rochelle, N. Y.
Williams, G. S.....Ithaca, N. Y.
Williams, R. B., Jr.,
New York City
Williamson, F. S..New York City
Wilson, C. W. S.,
New Rochelle, N. Y.
Wölfel, P. L...Philadelphia, Pa.
Wright, J. B.....New York City

Zook, M. A.....Plainfield, N. J.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, March 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership and ballots on the proposed amendment to the Constitution will be canvassed, and a paper by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., entitled "A High-Voltage Power Transmission," will be presented for discussion. This paper was printed in *Proceedings* for January, 1903.

Wednesday, March 18th, 1903.—8.30 P. M.—At this meeting a paper by George W. Lilly, Assoc. M. Am. Soc. C. E., entitled "Sand-Blast Cleaning of Structural Steel," will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, April 1st, 1903.—8.30 P. M. A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E.; and "Automatic Modules for Regulating the Speed of Filtration," by Charles Anthony, Jr., M. Am. Soc. C. E. These papers are printed in this number of *Proceedings*.

ADDITIONAL PAPER.

Attention is called to the paper entitled "Note on the Coefficient of Elasticity of Concrete and Mortar Beams During Flexure," by Myron S. Falk, Jun. Am. Soc. C. E., published in this number of *Proceedings*. This paper will not be presented for discussion at any meeting, but written communications on the subject are invited for publication, and its discussion may be called up by any member at any future meeting of the Society.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention of the Society will be held at Asheville, N. C., during the week beginning June 8th, 1903.

ACCESSIONS TO THE LIBRARY.

From January 14th to February 10th, 1903.

DONATIONS.*

FOWLER'S ELECTRICAL ENGINEER'S YEAR-BOOK AND DIRECTORY OF LIGHT, POWER AND TRACTION STATIONS, 1903.

Leather, 6 x 4 ins., 479 pp., illus. Scientific Publishing Company, Manchester. 2 shillings 6 pence, net. Post free, 2 shillings 9 pence.

The preface states that in this book the work of revision has been extensive. Much new matter has been inserted, and among the additions are practical notes on the designing and testing of dynamos and motors. Some information is also given on rotary converters and switch-boards, electric welding, etc. A little pruning has been done to afford space for the fifty or sixty pages of new matter which has been added and the extensions in other directions which were desirable. In an appendix is given a directory of electric light and power stations throughout the United Kingdom, which furnishes the principal particulars of the pressures and methods of distribution as well as of boilers, engines, and electrical equipment, of between 400 and 500 stations. There is an index of nineteen pages.

AMERICAN ENGINEERING PRACTICE.

In the Construction of Rotary Portland Cement Plants, Designed and Erected by Lathbury and Spackman, Philadelphia, Pa. Cloth, 9 x 11 ins., 157 pp., illus. G. M. S. Armstrong, Philadelphia, 1902. $2.00. (Donated by *Cement and Engineering News.*)

In the Announcement the authors state that they offer to those interested, photographic and other illustrations of some of the plants that they have designed and constructed, and of the machinery they contain, all of which they have installed.

MANUAL FOR RESIDENT ENGINEERS.

Containing General Information on Construction. By F. A. Molitor and E. J. Beard. Cloth, 7 x 4½ ins., 4 + 118 pp., 13 tables. New York, John Wiley & Sons, 1903. $1.00.

During the construction of the Choctaw, Oklahoma and Gulf Railroad Company's line across the State of Arkansas in 1899, the first fifty pages of this book were written by the authors and published in blue-print form as "Instructions" to their resident engineers, with a view of obtaining uniformity of method in both work and results. When the company, in 1901, entered upon some 500 miles of extensions and branches separated from one another, making personal supervision difficult and slow, the authors revised the body of the book, and also the standard specifications of the company, which, together with the tables of level cuttings, were added to the original instructions and published in book form for the railroad company's use. After three years of private circulation, the authors have decided to present the "Manual" to the profession generally, and to the younger members particularly, with the hope that it may be as successful in standardizing and simplifying the work of resident engineers throughout the country as it has been in the instance of one railroad. There is an index of five pages.

CATECHISM OF THE LOCOMOTIVE.

By Matthias N. Forney. Second Edition, Revised and Enlarged. Cloth, 8 x 6 ins., 16 + 709 pp., illus. *The Railroad Gazette*, New York, 1897. $3.50.

Since the first edition of this work, in 1873, many changes and improvements have been made in the construction of locomotives, so that in preparing a second edition of the book the first one had to be thoroughly revised, and, to a great extent, rewritten. Also a great deal of entirely new matter had to be added to bring it up to the present state of the art of locomotive engineering. Most of the illustrations are entirely new, and have been selected from the latest practice in this country. The chapter headings are: Force and Motion; Resolution of Motion and Forces; The Principles of the Lever; The Forces of Air and Steam; On Work, Energy and the Mechanical Equivalent of Heat; The Steam Engine; The Expansive Action of Steam; The Slide-Valve; The Action of the Piston, Connecting Rod and Crank; General Description of a Locomotive Engine; Different Kinds of Locomotives; Locomotive Boilers; The Boiler Attachments; The

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

Throttle Valve and Steam Pipes; The Cylinders, Pistons, Guide-Bars, Cross-Heads and Connecting-Rods; The Valve-Gear; Action of the Pistons, Cranks and Driving-Wheels; Adhesions and Traction; Internal Disturbing Forces in the Locomotive; The Running Gear; Miscellaneous; Friction and Lubrication; Screw-Threads, Bolts and Nuts; Tenders; Water-Tanks and Turn-Tables; The Westinghouse Air-Brake; The Care and Use of the Air-Brake; The Eames Vacuum Driving-Wheel Brake; Proportions of Locomotives; Combustion; The Resistance of Trains; Performance and Cost of Operating Locomotives; The Care and Inspection of Locomotives while in the Engine House; Running Locomotives; Responsibilities and Qualifications of Locomotive Engineers; Accidents to Locomotives; Accidents and Injuries to Persons; Properties of Steam; Hyperbolic Logarithms. There is an index of twenty-nine pages.

PROCÉDÉS GÉNÉRAUX DE CONSTRUCTION TRAVAUX D'ART.

Par A. de Préaudeau, avec la collaboration de E. Pontzen. Tome Second: Construction des Ouvrages. Paper, 10 x 6 ins., 3 + 612 pp., illus., Paris, Ch. Béranger, 1903. 20 fr. (Donated by Ernest Pontzen.)

The Contents are: Fondations à l'air libre, à sec et sous l'eau; Procédés de consolidation du sous-sol, accidents: Fondations à l'aide de l'air comprimé; Entretien et réparation des ouvrages, démolitions; Travaux en élévation; Prix de revient (fondations, travaux en élévation).

ENGINEERING FOR LAND DRAINAGE.

A Manual for Laying Out and Constructing Drains for the Improvement of Agricultural Lands. By Charles G. Elliott, M. Am. Soc. C. E. Cloth, 7½ x 5 ins., 8 + 232 pp., illus. New York, John Wiley & Sons, 1903. $1.50.

The preface states that this brief treatise on drainage engineering is intended for the use of those who are charged with the responsibility of making plans for and executing drainage improvements. It puts the experience and practice of years into a form which will be available to others who wish to acquire quickly the principles and practice of land drainage. It has been the purpose of the author to emphasize and make clear those points which the student, the busy agriculturist, and the practical engineer should know. The chapter headings are: Introduction; Soils; Land Drainage Practice; Levelling and Topography; Laying out Drains in the Field; Fixing the Grade of Drains; Maps and Records; Grading the Ditches for Tile; Flow of Water through Pipes; Size of Lateral Drains; Open Drains; Drainage of Barnyards, Cattle-Lanes, etc.; Road Drainage; Drainage Districts; Estimates of Cost; Benefits and Profits of Land Drainage. There is an index of ten pages.

STEAM POWER PLANTS, THEIR DESIGN AND CONSTRUCTION.

By Henry C. Meyer, Jr. Cloth, 9 x 6 ins., 159 pp., illus. New York, McGraw Publishing Co., 1903. $2.00.

The publishers' note states that the matter in this book was written to give information to owners or managers of manufacturing plants or buildings requiring power installations, since they are from time to time called upon to specify or purchase the machinery needed for the proper equipment of their buildings with a view to efficiency and economy in operation. It is believed that the book will also prove valuable to the engineer, architect or student who desires general information on the subject treated. To the expert it claims only to present in accessible and convenient form data useful in the practice of his profession. The Contents are: Design of Steam Power Plants; Proportioning Steam Boilers; Design of Tubular Boilers and Boiler Specifications; Selection of Engines; Specifications for Steam Engines; Steam and Water Piping; Condensers; Feed Water Heaters and Economizers; Mechanical Draft; Chimneys; Coal Handling, Water Supply and Purification.

THE MANUFACTURE AND PROPERTIES OF IRON AND STEEL.

By Harry Huse Campbell, M. Am. Inst. Min. E., M. Am. Soc. C. E., M. Iron and Steel Inst. Second Edition. Cloth, 9 x 6 ins., 29 + 862 pp., illus. New York, *The Engineering and Mining Journal*, 1903. $5.00. (Donated by the Author.)

In this present edition the author has tried to give in Part I a kind of introduction for those who are not metallurgists. It does not pretend to give all the qualifying conditions, but simply the main principles. Part II embraces the ground covered by the first edition of Structural Steel, but many chapters have been entirely rewritten, and a great deal of new matter added. Much of the text relating to the chemical history of the open-hearth furnace has been condensed from certain papers which the author contributed to the *Transactions* of the American Institute of Mining Engineers, while portions of chapters appeared in the *Transactions* of the American Society of Civil Engineers. The experiments and investigations have been conducted at the works of

The Pennsylvania Steel Company, of Steelton, Pa., and all the details of manufacture and treatment have been under the author's direct observation. In Part III the author has entered into a more comprehensive comparison of the industrial situation, and has compared the salient points of foreign and American practice. The Contents are: The Main Principles of Iron Metallurgy; The Errancy of Scientific Records; The Blast Furnace; Wrought-Iron; Steel; High-Carbon Steel; The Acid-Bessemer Process; The Basic-Bessemer Process; The Open-Hearth Furnace; Fuel; The Acid Open-Hearth Process; The Basic Open-Hearth Process; Special Methods of Manufacture and Some Items Affecting the Costs; Segregation and Homogeneity; Influence of Hot Working on Steel; Heat Treatment; The History and Shape of the Test-Piece; The Influence of Certain Elements on the Physical Properties of Steel; Classification of Structural Steel; Welding; Steel Castings; The Iron Industry of the Leading Nations. There is an index of twenty-two pages.

Gifts have also been received from the following:

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Rivières Canalisées. Par F. B. de Mas. Paris, Ch. Beranger, 1903.

The Analysis of Steel-Works Materials. By Harry Brearley and Fred Ibbotson. Longmans, Green and Co., London, New York and Bombay, 1902.

United States Official Postal Guide, January, 1903. Revised and Published Monthly by Authority of the Post Office Department. Contains an Alphabetical List of All the Post Offices in the United States with County and State, a List by States, a List by States and Counties, Showing the Money-Order Offices, Domestic and International; also, Rates of Postage; Synopsis of Postal Laws, Orders, Rulings of the Department; Information Relating to Postal Matters; and General Regulations Respecting Foreign Mails. Philadelphia, George F. Lasher.

SUMMARY OF ACCESSIONS.

From January 14th to February 10th, 1903.

Donations (including 10 duplicates)	111
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Total	114

MEMBERSHIP.

ADDITIONS.

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		Date of Membership.
ALLAN, PERCY		
Public Works Dept., Sydney, N. S. W., Australia	Assoc. M.	April 1, 1896
	M.	Oct. 1, 1902
BARNARD, EDWARD CHESTER		
Topographer, U. S. Geological Survey, Washington, D. C.		Dec. 3, 1902
DYER, ARTHUR JAMES		
Engr. in chg., Great Falls Power Co., Nashville, Tenn	Assoc. M.	Mar. 6, 1901
	M.	Feb. 4, 1903
FITCH, GRAHAM DENBY		
Capt., Corps of Engrs., U. S. A., U. S. Engr. Office, Little Rock, Ark		Feb. 4, 1903
SHERMAN, CHARLES WINSLOW	Jun.	Oct. 8, 1891
Div. Engr., Sudbury Dept., Met. Water-Works, 1 Ashburton Pl., Boston, Mass	Assoc. M.	May 2, 1900
	M.	Feb. 4, 1903
THOMPSON, HENRY CLARK		
Div. Engr., N. Y. C. & H. R. R. R., 42 Lorillard Pl., Fordham, New York City		Feb. 4, 1903
WISNER, GEORGE MONROE		
Asst. Chf. Engr., San. Dist. of Chicago, 1010 Security Bldg., Chicago, Ill		Feb. 4, 1903

ASSOCIATE MEMBERS.

ASHBAUGH, LEWIS EUGENE		
Asst. Prof. of Civ. Eng., Iowa State Coll., Ames, Iowa		Jan. 7, 1903
AUERYANSEN, FREDERICK		
Chf. Draftsman, Atlantic Ave. Impvt., L. I. R. R., 44 Court St., Brooklyn, N. Y.	Jun.	Oct. 5, 1897
	Assoc. M.	Dec. 3, 1902
BACON, GEORGE MORGAN		
624 Dooly Blk., Salt Lake City, Utah		Dec. 3, 1902
BANTEL, EDWARD CHRISTIAN HENRY		
Instr. in Civ. Eng., Univ. of Texas, 2600 Whitis Ave., Austin, Tex		Feb. 4, 1903
BRADSHAW, SAM WIGFALL		
Asst. Engr., Estimating Dept., Pennsylvania Steel Co., Steelton, Pa	Jun.	Oct. 2, 1900
	Assoc. M.	Feb. 4, 1903
DANA, RICHARD TURNER		
Railroad Location and Gen. Engr., Room 206, Bennett Bldg., New York City	Jun.	Sept. 11, 1900
	Assoc. M.	Feb. 4, 1903
DAY, EDWARD BLISS		
Office Engr., Burlington's Missouri Lines, Room 610, Globe Democrat Bldg., St. Louis, Mo		Feb. 4, 1903
FERGUSON, WILLIAM HASTINGS		
(Best & Ferguson, Cons. Engrs.), 16 Ferguson Bldg., Denver, Colo		Jan. 7, 1903

		Date of Membership.
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U. S. Eng. Dept., Fort McKinley, Portland Harbor, Me..		Jan. 7, 1903
JAUDON, HENRY SCUDDER		
Care, Birmingham Water-Works Co., Birmingham, Ala...		Feb. 4, 1903
MCKAY, GEORGE ALBERT		
Civ. Engr., U. S. N., Narragansett Bay Coal Depot, Newport, R. I.		Feb. 4, 1903
ROCKWELL, JAMES VINCENT		
Asst. Engr., C. & N. W. Ry., Eagle Grove, Iowa	Jun.	April 3, 1900
	Assoc. M.	Feb. 4, 1903
SHEPARDSON, JOHN EATON		
Shabbona Grove, De Kalb Co., Ill.		Jan. 7, 1903
TOMPKINS, EDWARD DE VOE		
Chf. Draftsman, Bureau of Yards and Docks, U. S. Navy Yard, League Island, Philadelphia, Pa.	Jun.	Feb. 2, 1897
	Assoc. M.	Dec. 3, 1902
WHEELER, RALPH NORMAN		
With Rapid Transit R. R. Comm., 13 Astor Pl., New York City		Jan. 7, 1903
WHITE, LAZARUS		
18 West 119th St., New York City	Jun.	May 1, 1900
	Assoc. M.	Feb. 4, 1903

ASSOCIATES.

KELLER, OTTO BALTHAZAR		
127 Fulton St., New York City		Feb. 3, 1903
QUIRK, EUGENE MCGRATH		
Mgr., Montreal Quarry Co., 266 Boulevard, Ville St. Louis, Montreal, Que., Canada		Feb. 3, 1903

JUNIORS.

BASSETT, ROBERT JAY	
25 North 4th St., Steelton, Pa.	Feb. 3, 1903
DOUGHERTY, RICHARD ERWIN	
244 West 20th St., New York City	Jan. 6, 1903
FUJINO, SHUKICHI	
Bridge Engr., Nippon Tetsudo Kwaisha, Tokyo, Japan...	Feb. 3, 1903
GEORGE, HUGH MELVIN	
Care, Water Co., Meridian, Miss.	Feb. 3, 1903
KOLB, HENRY JACOB	
Care, Dr. Dillworth, Bedford Park, New York City.	Feb. 3, 1903
PEARSE, LANGDON	
317 Walnut Ave., Roxbury, Mass.	Jan. 6, 1903
TOMBO, CARL	
273 West 138th St., New York City.	Feb. 3, 1903
WILDES, WALDO GILMAN	
208 Church St., Clinton, Mass.	Feb. 3, 1903

RESIGNATIONS.

MEMBERS.

	Date of Resignation.
See, Horace	Dec. 31, 1902
Walton, Charles Wallace	Dec. 31, 1902

DEATHS.

Barriger, John Walker, Jr.....Elected Junior, May 31st, 1898; Associate Member April 2d, 1902; died December 19th, 1902.

Fuertes, Estevan Antonio .....Elected Member February 17th, 1869; died January 16th, 1903.

Rich, Watson Wellman.....Elected Member September 5th, 1883; died January 12th, 1903.

Sweet, Elnathan.....Elected Member November 6th, 1878; died January 27th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(January 14th to February 10th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spèciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

El Paso & Southwestern Bridge at El Paso, Texas.* (40) Jan. 16.
The New Swing Span and Substructure for the Interstate Bridge, Omaha, Neb.* (13) Jan. 22.
The Damage to the New East River Bridge Cables by Fire and the Proposed Method of Repairing It. (13) Jan. 22.
Pebble Faced Bridge in the National Park, Washington, D. C.* W. J. Douglas. (13) Jan. 22.
Bridge across the Missouri River at East Omaha, Nebraska.* (15) Jan. 23.
Erection of the Northwest Miramichi Bridge, Newcastle, N. B.* H. D. Bush, M. Am. Soc. C. E. (15) Jan. 23.
The Elevation of the Chicago & Alton Bridge at Bridgeport, Chicago.* (40) Jan. 23.
The Rio Grande Braced Arch Bridge, Pacific Ry. of Costa Rica.* (18) Jan. 24.
The Omaha Interstate Bridge.* (14) Jan. 24.
The Substructure for the 1800-Ft. Cantilever Bridge at Quebec, Canada.* (13) Jan. 29.
Concrete-Steel Arch Bridges.* Daniel B. Luten. (Paper read before the Indiana Eng. Soc.) (60) Feb.
Wood Block Paving and Other Features in Connection with a Small Drawbridge in Brooklyn, N. Y.* (14) Feb. 7.
Le Viaduc du Viaur sur la Ligne de Carmaux à Rodez.* (35) Jan.
Le Viaduc Métallique du Viaur.* Emile Godfernaux. (38) Jan.
Calcul des Ponts en Maçonnerie.* Methode de M. Ritter. (33) Jan. 3.

Electrical.

Some Electrical Fire Hazards. Washington Devereux. (2) Jan.
Observations on the Ohmic Resistance of Electrolytes and Its Determination.* J. Wright. (26) Jan. 2.
Reducing the Measured DR of a Laid Submarine Cable to 75° F. and Atmospheric Pressure. J. Rymer-Jones. (26) Jan. 2.
Entropy. J. Swinburne. (26) Jan. 9.
Electric Power Transmission in a Cube Sugar Factory.* (26) Jan. 9.
A New Automatic Oil-Switch for High-Tension Circuits.* (13) Jan. 15.
The Hewitt Mercury Vapour Lamp and Static Converter.* (22) Jan. 16.
Middlesborough Electricity Works.* (26) Jan. 16.
The Electric Lighting of Erith (a Three-Phase Plant).* (26) Jan. 16.
Electrically-Operated Oil Circuit-Breaker for High Tension Circuits.* (15) Jan. 16; (27) Jan. 17; (20) Jan. 22; (18)Jan. 24.
Oerlikon Induction Motor with Four Speed Variations.* Hans Behr. (27) Jan. 17.
Excitation of Asynchronous Generators by Means of Static Condensance. A. S. McAllister. (27) Jan. 17.
Cooper-Hewitt Static Converter.* (27) Jan. 17; (17) Jan. 17.
The Construction of Aerial Telephone Lines.* Arthur V. Abbott. (27) Serial beginning Jan. 17.
Electricity as an Underground Motive Power. Wm. Little. (Paper read to the New Seaham Mining Students' Assoc.) (62) Jan. 22.
The Photometry of Electric Lamps.* J. A. Fleming. (Paper read before the Inst. of Elec. Engrs.) (11) Serial beginning Jan. 23; (Abstract of Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Jan. 17; (26) Serial beginning Jan. 2.
Stress on Frames of Alternating Current Generators. P. J. Frenell. (27) Jan. 24.
The Underground System of the Chicago Edison and Commonwealth Electric Companies. W. G. Carlton. (Abstract of Paper read before the Chicago Elec. Assoc.) (27) Jan. 24.
The Present State of Wireless Telegraphy.* (19) Jan. 31.
26 000-Volt Installation at Grenoble, France.* C. L. de Muralt. (27) Jan. 31.
Electrical Measuring Instruments.* Caryl D. Haskins. (3) Feb.
Richmond, Indiana, Municipal Electric Lighting and Power Plant.* J. B. Nelson. (Paper read before the Indiana Eng. Soc.) (60) Feb.; (Abstract of Paper read before the Indiana Eng. Soc.) (13) Jan. 29.
Machine Tools with Individual Electric Motors. R. T. E. Lozier. (10) Feb.
The Electrical Resistance of Bearings. A. E. Kennelly and C. A. Adams. (27) Feb. 7.
The Economic Value of Testing. Geo. D. Shepardson. (Abstract of paper read before the Northwestern Elec. Assoc.) (27) Feb. 7.
Structural Details of the Edison Storage Battery.* (46) Feb. 7.
The Cooper Hewitt Lamp and Static Converter.* (46) Feb. 7.
Bull System of Selective Wireless Telegraphy.* (27) Feb. 7.
Voltage Regulation.* (27) Feb. 7.
Compte Rendu du Congrès de la Houille Blanche. Ch. Pinat. (32) Nov.
La Nouvelle Usine Hydro-Électrique des Chutes du Niagara.* (33) Jan. 3.

Marine.

The Machinery of the Orient-Pacific Liner *Orontes.* (11) Jan. 2.
The Vibration of Steamships. George W. Melville. (11) Serial beginning Jan. 2.
Modern Marine Boilers. H. M. Rounthwaite, M. I. Mech. E. (Paper read before the Jun. Inst. Engrs.) (12) Jan. 9.
The S. S. *Brussels.** (12) Jan. 9.

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* Illustrated.

Marine—(Continued).

The Chilian Battleship *Libertad.* (11) Jan. 16.
Submarine Torpedo Boats, Past, Present and Future.* Lawrence Spear. (Abstract of paper read before the Society of Naval Archts. and Marine Engrs.) (19) Feb. 7.

Mechanical.

The Blast Furnace as a Power Plant.* Edward A. Uehling. (8) Jan.
Kansas Natural Gas; Its Control and Distribution; Method Employed in Burning It and in Measuring the Pressures.* W. R. Crane. (45) Jan.
Liquid Fuel for Electrical Stations. W. H. Booth. (26) Jan. 2.
Flame Analyses and Fuel Combustion.* W. H. Booth, M. Am. Soc. C. E. (26) Jan. 2.
Hydraulic Machinery for an Indian Locomotive Works.* (12) Jan. 2.
Sugar-Making in the Hawaiian Islands; Recent Practice in the Design, Construction and Operation of Raw Cane-Sugar Factories in the Hawaiian Islands.* J. N. S. Williams. (Paper read before the Inst. of Mech. Engrs.) (11) Serial beginning Jan. 2.
Comparative Economy of Stoking and Hand Firing.* Julius Geldard. (Paper read before the Leeds Assoc. of Engrs.) (47) Jan. 3.
Steam Pipe Covering Tests.* (47) Jan. 3.
The Use of Blast-Furnace Gas in Gas Engines. Cecil A. Cochrane. (Abstract of Paper read before the Cleveland Inst. of Engrs.) (47) Serial beginning Jan. 3.
An Inclined Retort-House and Its Working at Bristol.* (66) Jan. 6.
The Granton Works of the Edinburgh and Leith Gas Commissioners.* Walter Ralph Herring, M. Inst. C. E. (66) Serial beginning Jan. 6.
Turbo-Blowing Engine at the Farnley Iron Works.* (22) Jan. 9.
Single Rock Cutting Machine. (11) Jan. 9.
A Remarkable Steam Engine Test. (Tests made by Prof. J. A. Ewing.) (12) Jan. 9.
The Purification of Blast Furnace Gas.* (22) Serial beginning Jan. 9.
Testing Indicator Springs.* (Reprinted from *Machinery.*) (47) Jan. 10.
Efficiency Tests of Compressed Air Machinery.* W. C. Popplewell, A. M. Inst. C. E. (47) Serial beginning Jan. 10.
An English Inclined Retort Installation in Italy. (66) Jan. 13.
Freaks and Fallacies in Steam Engine Design. Egbert P. Watson. (62) Jan. 15.
Rules for Working Loads of Wire Elevator Ropes. H. C. Newcomer. (13) Jan. 15.
Fundamental Differences in the Construction of Gas and Steam Engines. P. Plantinga, M. Am. Soc. M. E. (13) Jan. 15.
The Elimination of Hand Labor in Brick Making.* J. Parker B. Fiske. (13) Jan. 15.
The Lanchester Motor Car. (11) Jan. 16.
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PAPERS AND DISCUSSIONS.

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SAND-BLAST CLEANING OF STRUCTURAL STEEL.

By George W. Lilly, Assoc. M. Am. Soc. C. E.

To be Presented March 18th, 1903.

It is intended to set forth, in this paper, some of the results which have been attained in the use of the sand-blast in cleaning steel plates and structural steel. Some data as to the cost and other elements which enter into its application will be presented, in the hope that possibly something may be added to the facility of making approximately accurate estimates of the cost of any sand-blast cleaning which may be in contemplation hereafter. Some of the work heretofore done has been referred to in a paper, published in *Engineering News* of April 24th, 1902; and in it the cost of cleaning 12 600 sq. ft. of the Front Street Viaduct over the Little Miami Railroad, in Columbus, Ohio, was stated. In presenting the experience gained in the continuance of the work during the season of 1902, giving results in cleaning a total area of 135 500 sq. ft. on viaducts in that city, which have been repainted since the early part of November, 1901, it is hoped to add a record of at least some value.

If it leads to a thorough discussion, and if members of the Society add to the record, the most important part of the purpose in presenting this paper will have been realized.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

During the past few years some attentio n has been given to attempts to secure thorough cleaning of structural steel before the application of the preservative coating; but, unfortunately, we are still far from the realization of the kind of work which should be required. Much has been written relative to the kind of paint which will best preserve the steel and iron used so extensively in a great variety of structures. In the discussion, which has been going on for many years, many have argued very strenuously against, and many just as earnestly in favor of, perhaps every kind of paint now used largely as preservatives of ferric structures from the ravages of rust and corrosion. But, in the discussion, they have often lost sight of the very important matter of cleaning the steel properly. On account of the great deterioration of such structures, in the past, whether by reason of exposure to the weather on land or at sea, or to the action of acids, or the gases and moisture of coal combustion, in combination with the oxygen of the atmosphere, this is a question of vital interest to all engineers and others concerned in their erection or maintenance. Nevertheless, comparatively little has been done thus far toward securing such cleaning as will insure a much longer life for, as well as economy in the maintenance of, such structures. The dawn of a better day seems to have appeared, in the application of better methods, in some instances, on new work, and, in more cases, on the old; and it is to be hoped that the full light of that day may soon be seen, in the results on new work in the shop—as a provision for the future—and on old structures—to undo, as far as possible, the neglect of the past.

It has often been observed that mill marks made with paint of a very inferior quality have afforded good protection to steel, while other portions, covered with a much better paint, have been much affected by rust, the latter even extending under paint which, for the most part, has still retained its continuity and elastic qualities. The explanation is found in the facts that the mill marks were made when the metal was clean, and that the paint applied subsequently was spread upon the mill scale, rust and grease which had accumulated upon it before the shop work was finished. However excellent may be its qualities, it is absurd to expect any paint to preserve steel to which it is applied, unless the mill scale, rust, dirt and grease have been first removed. This observation applies with equal, or, it may be said, with even greater, force, to the repainting of old structures which have been

neglected, and upon which rust and corrosion have proceeded so far that it is impossible to secure good preservation by ordinary methods of cleaning. Having this knowledge in mind, it is proper to determine, from the conditions met in any case, what is necessary to be done in order to insure that the preservative coating shall be applied only after the surface of the metal is clean and in proper condition to receive it. To accomplish this, there is no doubt that much of the new as well as old steel will be required to be cleaned by means of the sand-blast, as the only practicable and effective method. Much of the steel, after leaving the mills, is stored out-of-doors and exposed to the weather for a considerable length of time before the shop work is done. Thus its rusting often progresses to such an extent that the ordinary process of cleaning with wire brushes, even if that be attempted, is not sufficient to permit the paint to come into immediate contact with and become firmly adherent to the metal. The quality of the paint used, on new structures as well as old, is an important matter; but that cannot be discussed in this paper.

The effectiveness of the sand-blast process depends upon the ability of sand, used as a projectile, to break up, wear away and remove the substances against which it is directed, when actuated by a current of compressed air. All the machines, often called mixers, for the application of this process, are intended to secure the introduction of the proper proportion of sand into a current of compressed air passing through a pipe. This current of compressed air, bearing with it the sand thus introduced, is then directed into and through rubber hose, preferably 2¼ or 2½ ins. in diameter, and a steel or iron nozzle of suitable size, and against the surface to be cleaned. Sometimes the air-blast alone may be used to remove dust and soot. Such an appliance was first invented and patented by General Benjamin C. Tilghman, the patent being issued on October 18th, 1870. This appliance, as improved by Mathewson, is still on the market. In this apparatus, a slotted slide, operated by a lever, regulates the quantity of sand introduced into the current of air. This is shown by the sectional drawing, Fig. 1.

In the Paxson-Warren machine, Fig. 2, the feed of the sand is regulated by a revolving piece, or valve, which covers the opening in the bottom of the hopper to the extent desired to let the proper quantity of sand fall through it and into the air pipe.

In the machine patented by J. M. Newhouse, of Columbus, Ohio, shown in Fig. 3, the sand passes from the hopper at the bottom through an annular opening around the end of a nozzle-shaped steel piece, which decreases in its outer circumference toward the end; and, by raising or lowering it, this annular opening may be increased or diminished in size. The distinguishing feature of this appliance is

MATHEWSON'S SAND-BLAST.
(TRADE NAME, TILGHMAN.)

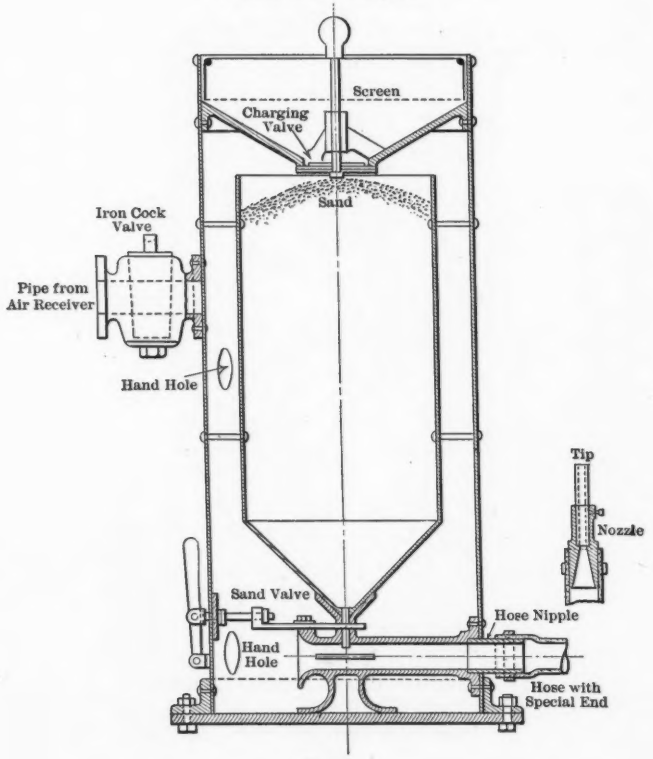


FIG. 1.

the use of this nozzle as a siphon, with its perforations as shown. The small holes permit part of the air which flows through the small pipe and the siphon to escape outwardly through the surrounding sand, thus stirring it up and preventing it from clogging at the opening. A similar siphon, without the perforations, is placed in the air pipe.

Possibly there are other machines, but the writer is not familiar with them. Any of the sand mixers may be made with two chambers, with valves arranged so as to lock the sand through the upper one into the lower one while the sand-blast is in operation.

The greatest merit of the sand-blast is that it removes from the surface of the metal every trace of dirt, scale, rust and grease, and

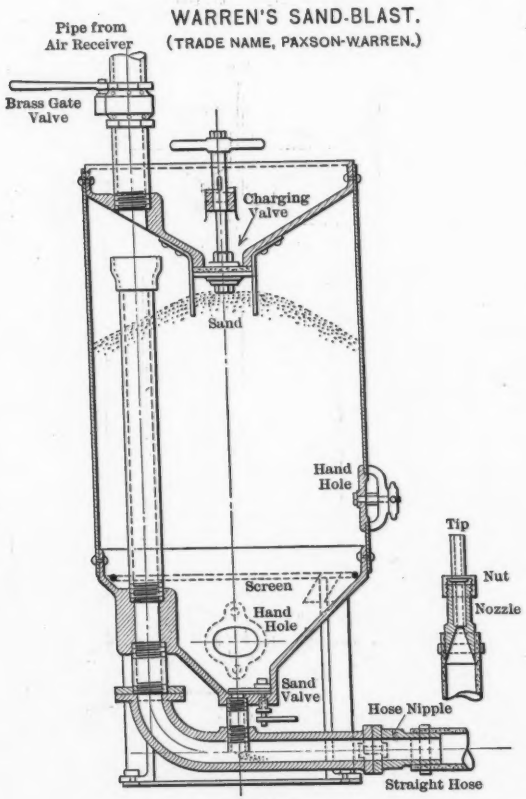
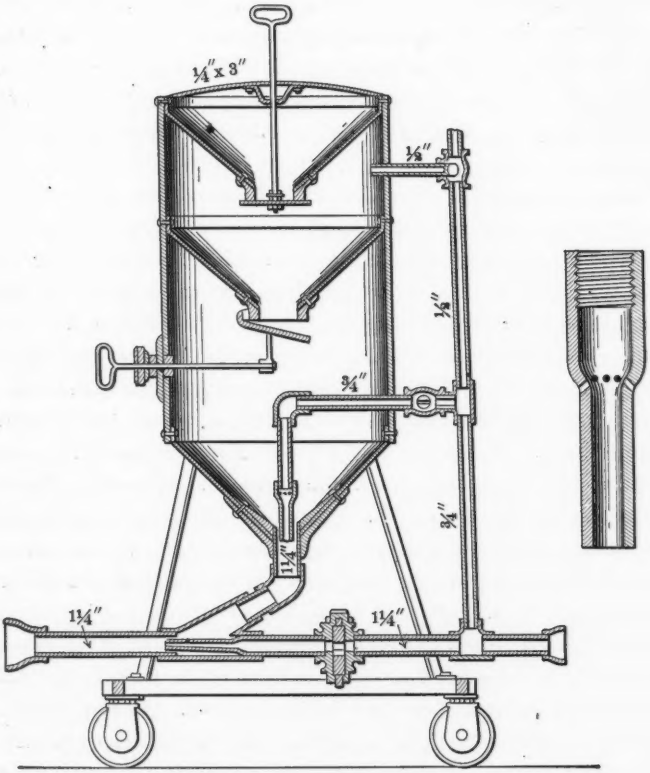


FIG. 2.

the bright metallic surface is everywhere exposed and perfectly clean. This is an ideal condition to secure the strong adhesion of the paint, so that, as far as it is possible, it will protect the metal. The thoroughness of the cleaning effected by the sand-blast is noted especially upon metal surfaces which have been pitted by rust and corrosion to a considerable degree. The pits are thus cleaned as thor-

oughly as other places. It also reaches and cleans effectually every portion, in re-entrant angles and on the edges of the different sections of a beam, girder or post, on and around rivet heads, and in many other places either entirely inaccessible to the wire-brush or steel scraper, or on which they are used with great difficulty and little effect.



THE NEWHOUSE SAND-BLAST.

FIG. 3.

Such places cannot be cleaned thoroughly by hand, even with the most diligent effort. Even plane surfaces of considerable area, on old structures requiring repainting, especially where covered largely with scales and rust, cannot be thus cleaned so as to remove all the dirt, rust, scale and disintegrating paint. There will still remain sufficient rust and scale to separate slightly the paint from the metal,

so that there is not the intimate contact and firm adhesion necessary to prevent the rusting process. The continuity of the coat of paint will soon be broken at places, and, moisture and gases in the atmosphere coming in contact with the metal, rust will be formed even under places where the paint remains intact.

Paint applied to such surfaces can often be stripped off like the peel of an orange, and still remains tough and elastic. Good paint, it may be, but it has never taken a good hold on the steel. On the other hand, the writer has seen a piece of old steel, which was cleaned and painted with red lead in 1899, on which the paint will not peel off at all, but may be cut away, still leaving the under portion tightly adhering to the steel.

The sand-blast has been found serviceable and economical for other purposes than the cleaning of steel plates and structural steel. It is used in cleaning iron and brass castings, either by the direct application of the blast, or by introducing the sand-blast through the hollow trunnion of the tumbling barrel in which the castings are placed. The inner, as well as the outer, surfaces of castings are thus cleaned, and the sharp lines of the edges preserved, while the cleaning effected by the tumbling barrel without the sand-blast tends to round off the corners. Its use to clean street-railway rails and fish-plates, for cast and electric welding, is familiar to all. It is also quite effective in cleaning cut-stone work. One of the ice-manufacturing companies of Columbus, Ohio, has recently purchased a sand-blast machine for use in removing from its condenser pipes the lime scale formed from the hard water used.

The Columbus Railway Company has made use of it in cleaning about 18 ins. in length of a large number of its iron trolley poles, just above and below the surface of the ground. At this point the poles had rusted to such an extent as to weaken them materially, and it would soon have been necessary to replace many of them. After cleaning in this way, a coat of paint was immediately applied, and, soon afterward, each pole was encased in a cylinder of cement mortar tamped into removable forms.

The sand-blast has also been used at the shops of the Pan Handle Railway, and in other railroad shops, in cleaning the tenders of locomotives before repainting. A great saving of expense is thus realized, and superior work is obtained. It would be attempting too much to

take up the methods and relative costs in these various lines of sand-blast work.

It seems that, beyond a few scattered experiments, only during the past six or seven years may be found any published record of the application of this process to the cleaning of structural steel. And, even in these recent years, no very great amount of such cleaning has been done. Most of the trials heretofore made have been upon a somewhat experimental basis, and yet something may be learned from them. It is still rather problematical as to how cheaply the mill scale, rust and grease could be cleaned from new steel plates and structural steel, if an efficient permanent plant were provided for the purpose. Some new plates for the bilge keels of the *Massachusetts* were cleaned at the United States Navy Yard, Brooklyn, in April, 1897. With one nozzle, 3 155 sq. ft. of surface were cleaned in 11 hours. This is at the rate of 286.8 sq. ft. per hour. The cost of the work was 0.56 cent per square foot. Upon this basis the writer estimated that the sand-blast cleaning of new steel plates, I-beams and other sections, would cost from 50 cents per ton, for very heavy sections, to $1.75 per ton, for light sections. This would not be a very large additional expenditure upon steel structures, considering the longer life which it would, no doubt, insure for the steel thus treated. The rapid deterioration and wasting away which has been observed on bridges and other structures may well cause builders of steel-framed buildings to consider the advisability of cleaning the steel in this way, before painting it and hiding it from inspection in the walls. The safety as well as the durability of such buildings may depend upon better provision against the rusting out of these steel frames. Who knows?

The steel for the anchorages of the cables of the New East River Bridge were cleaned by the sand-blast, under the direction of L. L. Buck, M. Am. Soc. C. E., Chief Engineer. This was done for the special reason that it would be "buried in the masonry, and would be totally inaccessible for all time." This process was also used on some of the steel in the Boston subways, Howard A. Carson, M. Am. Soc. C. E., Chief Engineer. The writer has no figures as to the cost in these cases.

Much of the expense of repainting in the future would be saved if greater care were taken in securing thorough cleaning at the shops before applying the first coat of paint to new work. If this is to be

accomplished, it will in many cases be found necessary to use the sand-blast; but this will not be done until the purchaser is willing to pay for it; and he must be convinced of its necessity and ultimate economy before he will be willing to do so. When there is a demand for it, the shops will be equipped with the necessary machinery, and will be able to do it more cheaply. At present, one shop has to bid against the other, and, none of them being required to make bids with such cleaning as a part of the specifications, the bids are such that the shops probably cannot afford to clean the steel properly, in some instances at least. They are averse to this process because of the expense of fitting up for it, the delay in getting the work out, and the cost of handling. Therefore the purchaser must be the prime mover in securing such work.

In the cleaning of old structures for repainting, this process has been more extensively applied, and, therefore, there are better data relative to such work than as to the cost of cleaning new steel at the shops. The necessity of its use to preserve old structures requiring repainting is more apparent than the more remote future saving of the expense of its application for repainting, by a much smaller outlay to secure thorough cleaning before erection.

During the latter part of March and the first two days of April, 1897, the bottom of the United States Steamship *Atlanta* was cleaned at the United States Navy Yard, Brooklyn, by means of the sand-blast, the plant used being furnished by Ward and Nash, of 26 Whitehall Street, New York City, who had the contract for the work. Its cost was 4.24 cents per square foot; but the work was done on a more or less experimental basis, and, with the added experience of the past six years, and a more perfect plant, it could probably be done for much less.

The work done on the One Hundred and Fifty-fifth Street Viaduct, in New York City, under the direction of E. P. North, M. Am. Soc. C. E., Consulting Engineer, during the year 1897, is familiar to all.* The cost of this work was reported as averaging about 13 cents per square foot, ranging from 20 cents, at the first, down to a little less than 10 cents, in the latter part of the work of cleaning 50 000 sq. ft. of surface. The pressure of compressed air then used was only about 20 lbs. at the sand-blast apparatus, which is without doubt too low a pressure

* *Engineering News*, September 23d, 1897, p. 198; *The Engineering Record*, September 25th, 1897, p. 356; and other engineering periodicals.

for the efficient removal of scale such as had accumulated there. It would seem, from recent experience, that a pressure of 35 lbs. would have been much more effective. This is true, because the viaduct was covered to a considerable extent with heavy rust scale and four layers of old paint, and a pressure of 35 lbs. would have made the sand projectiles much more efficient in breaking up and throwing off such scale. M. E. Evans, Assoc. M. Am. Soc. C. E., who was in immediate charge, estimated that the 600 000 sq. ft. of the painting surface of the viaduct could be cleaned for about 7.5 cents per square foot. It is quite probable that this could be done now at half that estimate, at least on all portions of the viaduct except the members having a very small extent of surface, where much sand and air are wasted in missing the steel along the edges.

The next work of this kind reported upon was the cleaning of the iron lock-gates and a portion of the aqueduct of the Muscle Shoals Canal, during the years 1898 and 1899, under the engineers of the United States War Department. The first report of this, made before its completion, is found in the House Documents for 1898–9.* This covers the work done to June 30th, 1898; and, on page 1926, Major Kingman states that the cost for cleaning was about 2.3 cents per square foot. In the report† of Sydney B. Williamson, M. Am. Soc. C. E., made after the completion of the work in 1899, the cost of cleaning 49 664 sq. ft., and painting it with red lead, is stated to be $0.0588 per square foot. Allowing a reasonable amount for the painting, it is probable that 3 cents per square foot would be very near the cost of the cleaning alone. In this case the plant was erected on a barge, roofed over, and was very well arranged to accomplish the work. The cost of the plant was included in this statement, and the same plant could be used for continuing such work. This cost was about one-third of the whole cost of cleaning and painting.

During the year 1899 the Pittsburg, Cincinnati, Chicago and St. Louis Railway Company used the sand-blast for cleaning the columns and girders supporting its buildings over the railroad tracks, along the east side of the High Street Viaduct, in Columbus, Ohio. The girders support brick arches, and there are no buckle plates. They are subjected to the blast, gases and steam from the large number of locomotives passing to and from the Union Depot, and freight and

* War Department Reports, Engineers, Part 3, p. 1925 *et seq.*
† Engineer's Report, Part 3, p. 2289, House Doc. for 1899 to 1900.

switch engines passing under them at frequent intervals. This company also cleaned part or all of a bridge at Akron, Ohio. No accurate account was kept of the cost and the area cleaned; but, from the best available information, it is estimated to have been about 3 cents per square foot. J. M. Newhouse, the inventor and patentee of the Newhouse sand-blast, is foreman for this company, and his apparatus was used in doing the work.

The City of Columbus, Ohio, has six viaducts in the vicinity of the Union Station, by which the streets pass over the railroad tracks. All the railroads passing through the city, except one, enter and leave the Union Station under the Fourth Street Viaduct near the east end, and the High Street Viaduct near the west end; and some of them pass under each of the other viaducts, one to the west and three to the southwest from the High Street Viaduct. Besides the freight and passenger trains passing under them, much switching is done under each by the yard engines. Hence, all these viaducts have been attacked seriously by rust and corrosion; and, on the portions most exposed to the blast, steam and gases from the locomotives, nearly all the paint has been destroyed and the metal consumed to a considerable extent. The Fourth Street Viaduct has been injured most, and two years ago it was cleaned by hand and repainted. This viaduct was erected in 1891, and was repainted in June, 1894, in September, 1896, and again, at the time above mentioned, in the fall of 1900. When the last repainting was progressing it was found necessary to replace with new ones seventeen of the 7-in. I-beams supporting the plank floors of the sidewalks over the tracks most used by freight trains and yard engines. Fig. 1, Plate XVI, is from a photograph of three of these I-beams, taken after their removal, after nine years' service. At the time this was done, the lower flange-angles of many of the stringers supporting the buckle-plates under the roadway had been rusted away until very thin; and in places the horizontal legs of the angles had been partly eaten away, so as to narrow them to about half their original width. These, however, were still considered of sufficient section to last for a time, and were not replaced then. The viaduct was painted under a contract, and considerable care was taken in trying to clean it as thoroughly as possible with steel scrapers, brushes, chisels and hammers. The hammers were often vigorously used to jar the scales loose by blows against the steel, and then scrapers, chisels and wire brushes used to complete the work.

At that time the sand-blast was suggested by the Engineering Department, but was not used. With as thorough work as could be done, many scales, so tightly cemented to the steel that they could not be detached, were loosened, upon the application of the first coat of paint, by the softening effect of the oil acting upon the cementing rust. The paint then applied began to scale in places within six months thereafter, partly due to the inferior quality of the first coat of paint and partly to the rust, soot and scale left upon the steel when repainted. The flange-angles of the floor stringers continued to waste away, and, in the summer of 1902, it was found necessary to replace, by new ones, the two angles of the lower flange on each of ninety floor stringers. The need of this is apparent from Plate XV, which is a photograph of some of the angles taken after their removal.

The new angles were surrounded with a covering of Portland cement mortar, 1 to 2 mixture, about ¾ to 1 in. thick. This was rammed under the lower surface of each beam, between it and a plank form, which was left to hold it against the steel until it had set for 48 hours. A wire netting, four meshes to the inch, secured by sheet-iron fasteners placed on the rivets as they were driven, was placed so as to surround the lower flange-angles before the cement mortar was applied. The cement covers the angles and netting completely, and is expected to protect them from rust. After seven months the cement is still intact, and shows no sign of cracking.

In view of the rapid deterioration of the viaducts of the city, and the prospect of having to replace them in a few years unless something were done to arrest it, the city authorities were induced to adopt the sand-blast as a means of cleaning them before repainting. Julian Griggs, M. Am. Soc. C. E., Chief Engineer of the Department of Public Improvements, had been very earnest in the advocacy of this course, believing it to be the only one that would be effective. Accordingly, in November, 1901, the work was commenced on the Front Street Viaduct, over the Little Miami Railroad, and 12 600 sq. ft. were cleaned and repainted, under the supervision of the writer as engineer in charge. When the weather became suitable for it, in April, 1902, the work was resumed and continued on this and the other viaducts named until the middle of November. The cleaning done amounted, in all, to 135 500 sq. ft. of surface. The cost and other data relative thereto are shown in Table No. 1. Four viaducts and

the south span of the High Street Viaduct were completed. It is likely that the other three spans of the High Street Viaduct, and the Fourth Street Viaduct, will be cleaned and repainted during the coming season of 1903.

It was impracticable to secure good contract work at a reasonable price, and all the sand-blast cleaning, as well as the painting, was done by men hired by the day. Two Newhouse sand-blast machines, mounted on light trucks, so that they could be moved about and placed where convenient for the work, were used in cleaning the viaducts named in Table No. 1. A wire-bound, 1½-in., rubber air-hose, 50 ft. in length, connected each machine with the 2-in. air pipe. Old rubber hose, which was much cheaper than new, was used for the sand hose, part of it being 2¼ and part 2½ ins. in diameter. The nozzles used were ½-in., extra heavy, gas pipe, of various lengths, from 12 to 24 ins. A length of at least 12 ins. seems to direct the blast with more effect than a shorter one. This was used instead of tool steel or other hard pipe because it was believed that it would last nearly as long and cost much less. The average length of time one nozzle lasted was about 5 hours, as shown by the length of pipe used and the total hours run. The nozzle was connected to the sand hose by a heavy, special cast reducer, about ¾ in. thick. This is shown in Fig. 2, Plate XVI, which also shows a blower used at the High Street Viaduct. This reducer was made thick, to sustain the wear caused by the deflection of the sand into the small nozzle pipe. The most severe wear of the nozzles is at a point 3 ins. from the connection with the reducer. The four worn nozzles, in Fig. 3, Plate XVI, show the characteristic form of the failure of the nozzles when worn out. The one at the right was selected as a rare exception, it being worn out at the outflow end. The three-part nozzle at the left wore out toward the center, and also just outside of the bushing, in which the three ¼-in. pipes were set with babbitt metal. This nozzle was made only for the purpose of a test, which is recorded in Table No. 2. After the test, it was used until worn out, and lasted, in all, 1 hour and 19 minutes.

It will be noted that the sand, in passing from the large sand hose to the small nozzle, is deflected so as to produce a cross-fire, striking with greatest force against the sides of the small pipe near the reducer end. A like wear upon the rubber sand hose occurs near its connection with the pipe from the machine, which is a 1¼-in. pipe, and the



CORRODED ANGLES FROM FOURTH STREET VIADUCT, COLUMBUS, OHIO.

spreading out of the sand to form the larger stream causes it to strike against the sides and then deflect to follow the direction of the hose. One foot in length, or sometimes a little more, cut from this end of the hose occasionally, fitted it for further use. The length of sand hose used varied from 25 to 65 ft., being regulated by the distance of the work from the place where the machine had to be placed. As the machines could not be placed upon scaffolding, in this work, at least 35 ft. of hose were required on nearly all the work, so as to reach from the ground to the floor system, from 16 to 20 ft. above the tracks, and in some places out over the tracks as far as 30 to 40 ft.

The nozzlemen should be men of some judgment and intelligence, so that they will understand how to manage the nozzle to make the blast most effective. In Fig. 4, Plate XVI, a nozzleman is shown in costume ready for work. The helmets worn were of tin, with cloth curtains hanging to the shoulders to keep out the dust, as far as possible. Instead of using wire gauze in the helmet, two pieces of glass were used for the nozzleman to see through, because it excluded the dust more effectually. When frosted over by rebounding sand, the glasses were removed and new ones inserted. After a little experience, a good nozzleman will learn how to hold the nozzle in any given case, varying its distance from the working point according to the manner in which he finds it is operating. Heavy scale requires him to hold the nozzle close, and light cleaning can be done more rapidly by holding it farther away and permitting the blast to spread somewhat and thus cut a wider swath. On moderately hard places about 5 to 6 ins. is the proper distance. To make it clean most rapidly he must also direct the blast so as to cut a swath clean as he goes, passing first in one direction and then in the other, across the member being cleaned, so as to leave no spots to which he must go back and thus waste the force of the blast on clean metal around them. The nozzle should generally be directed so as to strike the surface at a slight inclination from the normal, say 20 to 30° away from the nozzleman, thus blowing the dust and sand away. The cleaning should be carried forward from the nozzlemen, so that the blast will always act upon the exposed edge of scales, rust, or old paint, and, by getting under any loose portions, throw them off without first having to break them up.

The compressed air was supplied by the Union Depot Company, from a compressor with an air cylinder of 14 ins. diameter and a stroke

of 12 ins., compressing the air to a gauge pressure of 50 to 60 lbs. The number of strokes was regulated automatically so as to keep the pressure nearly constant. The air was led from the compressor to a large receiver, and then, by a line of 2-in. steel pipe, to a small receiver at the viaduct where the work was to be done. From this receiver (having a capacity of about 9½ cu. ft.) the air was conducted to the sand-blast machines. The pressure at the machines was usually from 30 to 40 lbs. The requisite length of 2-in. pipe varied from about 1 250 to 2 200 ft. The small receiver had a pet-cock in the bottom to let out accumulated water, and it removed much of the moisture from the air used.

The compressed air was paid for by the city, at the rate of 40 and 45 cents per hour for one machine, and 60 cents per hour for two machines in operation. For 18% of the time only one machine was in operation. This made the work cost more, because two machines could have been operated for about one and one-half times what one would cost. A foreman, two nozzlemen and three laborers could operate two machines and dry the sand for them. The foreman was paid 35 cents, nozzlemen 25 cents, and laborers 15 cents during one-half of the time and, after that, 17½ cents per hour.

The sand used was from Lake Erie. An attempt was made to secure rather coarse, clean and sharp sand; but it was at times impossible to do this without some delay, and some of the sand used was too fine and made much dust on account of the silt it contained. The sand was at first dried in two old locomotive ash pans, with old ties for fuel. This required almost constant attendance by one man, to stir it up and keep it from becoming so hot as to make the grains brittle and ineffective.

About May 1st, 1902, the dryer shown in Fig. 1, Plate XVII, was made by fitting a sheet-steel hopper on an old cast-iron stove. The wet sand would not fall through the ¾-in. holes in the lower part of the hopper, but would as soon as dry. The sand was permitted to cool for a few hours before being used, as hot sand caused steam and was likely to choke the small opening in the bottom of the hopper, around the end of the siphon nozzle. The objection to this kind of a dryer is that the fire-pot, being surrounded by sand in contact with it, burns out in a short time. Two fire pots were required in six months' service.

All the viaducts named in Table No. 1 have buckle-plate floor sys-



FIG. 1.—CORRODED I-BEAMS FROM FOURTH STREET VIADUCT, COLUMBUS, OHIO.



FIG. 2.—SAND-BLAST NOZZLE REDUCER AND BLOWER.

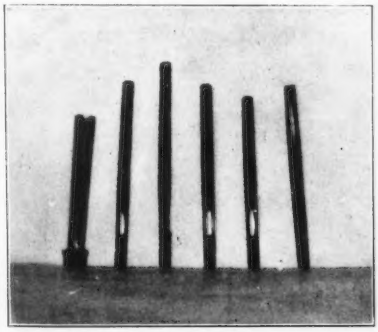


FIG. 3.—WORN-OUT SAND-BLAST NOZZLES.



FIG. 4.—SAND-BLAST NOZZLEMAN, IN WORKING COSTUME.

tems, exposing a large amount of steel surface to the action of rust and corrosion. It may be well to state the conditions under which the work of cleaning had to be done, in order to give a better understanding of the items making up the cost. The data here given may then be better analyzed and applied to any other proposed sand-blast cleaning. The first four viaducts named were erected during 1893 and 1894, and all were repainted during August and September, 1896, and none of them had been repainted since that time. High Street Viaduct was erected in the latter part of 1893, repainted in August, 1896, and again in October, 1899. The cleaning done before repainting, in each of these cases, was only hand-cleaning. All appearances indicate that the steel of the Front Street Viaduct over the Pittsburg, Cincinnati, Chicago and St. Louis, and the Cleveland, Cincinnati, Chicago and St. Louis Railways, must have been in better condition than that of any of the other viaducts, and a better quality of paint must have been applied at the time of its erection. This is judged largely from the condition of the portions of the viaducts above the level of the street pavement and protected by it from the direct action of the blast and gases from the locomotives. The portions below the pavement, on all the others, are subjected to greater wear by the locomotive blast on account of their small clearance above the stacks, their clearance above the level of the railroad tracks being only 16.33 to 16.75 ft., while this viaduct has a clearance of 20.33 ft. In cleaning them, therefore, it was impossible to swing any staging below the clearance elevation, in the case of four of them. The Front Street and the Naghten Street Viaducts do not afford sufficient space above the lower surface of the plate girders in which a man can work, and it was necessary to work from movable trestles, about 12 ft. high, made as light as possible, so that they could be moved off the tracks whenever a train or an engine was about to pass, and be replaced and the work continued when the track was clear. This may be seen in the view of the Front Street Viaduct, Fig. 2, Plate XVII.

Under the first three viaducts mentioned in Table No. 1, there are two main tracks and one side track, with a spur track from the middle of the first, making four tracks under the east half of it. The photograph of this viaduct was taken from a point very near the outer rail of the side track and west of the viaduct, and does not show the other tracks.

TABLE No. 1.—Cost, etc., of Sand-Blast Cleaning of Viaducts at Columbus, Ohio.

Location of viaduct.	Cost of labor.	Cost of flagmen.	Cost of compressed air.	Sand Used.		Dryer, sand-blast, scaffolding, etc.	Total cost.	Number of square feet cleaned.	Cost per square foot.	Square feet cleaned with 1 cu. ft. of sand.	Square feet cleaned per hour by one sand-blast.	Average pressure at sand-blast, in pounds per square inch.
				Cubic yards.	Cost.							
Front St., over Little Miami Railroad	$385.30	$45.15	$139.40	54.00	$78.55	$56.68	$705.08	24 900	$0.0283	17.1	64	35
Naghten St., " " "	140.74	17.85	56.40	28.44	42.41	32.52	289.92	8 000	0.0362	10.4	49	37
Maple " " "	223.00	11.90	94.80	34.50	58.08	58.70	446.48	17 000	0.0263	18.2	66	35
Front St., over Pittsburg, Cincinnati, Chicago & St. Louis and Cleveland, Cincinnati, Chicago & St. Louis Railways	670.66	.....	229.80	98.65	$107.49	87.18	1 095.07	63 000	0.0174	25.2	89	30
High St. (South Span)	961.20	.....	319.94	129.91	161.47	122.46	1 555.07	22 600	0.0688	6.1	23	33
Totals and Averages	$2 970.90	$74.90	$840.34	339.50	$447.94	$357.54	$4 091.62	185 500	$0.0202	14.8	54	33
Excluding High St. Viaduct	.....	.....	.....	.....	.....	.....	2 536.55	112 900	0.0325	20.0	74	33

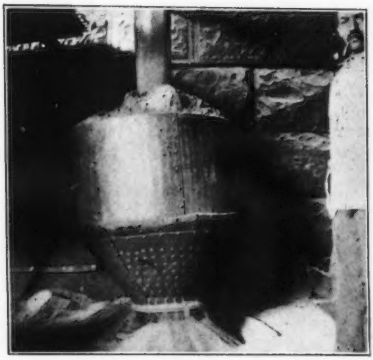


FIG. 1.—SAND DRYER.



FIG. 2.—FRONT STREET VIADUCT, COLUMBUS, OHIO.



FIG. 3.—PART OF GIRDERS AND BUCKLE-PLATES OF MAPLE STREET VIADUCT, COLUMBUS, OHIO.



FIG. 4.—PART OF NORTH SPAN OF HIGH STREET VIADUCT, COLUMBUS, OHIO.

The movable trestles were also used, part of the time, in cleaning the cover plates on the bottoms of the girders and the portion of the work along the abutments of the Maple Street Viaduct; but a large portion of the cleaning was done from staging resting upon the lower cover plates and angles of the plate girders. Fig. 3, Plate XVII, shows a portion of the girders and buckle-plate when all except a small portion of the buckle-plate and the web of the girders, where scale can be seen, had been cleaned and given a coat of red lead. Two more coats, of a paint less susceptible to the action of combustion gases, were applied afterward, as on all the viaducts.

To secure the safety of the men while at work on these three viaducts, when using the trestles over the tracks, it was necessary to have flagmen to give warning of the approach of trains, so that the trestles could be removed in time to avoid the danger. On the Maple Street Viaduct flagmen were not needed for so large a proportion of the time as on the other two viaducts. The cost of flagmen alone amounts to about 0.2 cent per square foot on the first two in Table No. 1, and 0.07 cent on the Maple Street Viaduct. The time lost on account of trains and switch engines sometimes amounted to one-fourth of the working time. If there had been no interruption by trains, and if flagmen had not been required, a fair estimate, from approximate calculations, based on records of the time lost each day and the cost of flagmen would reduce the cost fo the work to about the following figures: Front Street Viaduct, 2.3 cents; Naghten Street Viaduct, 3 cents, and Maple Street Viaduct, 2.45 cents, per square foot. Matched flooring screens, fastened with copper nails, were placed immediately over the main tracks and under the floors of these three viaducts, to protect them from the blast from locomotives.

In the Front Street Viaduct, over the Pittsburg, Cincinnati, Chicago and St. Louis and the Cleveland, Cincinnati, Chicago and St. Louis Railways, in which the clearance was 20.33 ft., the staging was supported on iron hangers which reached 2 ft. below the lower flanges of the floor beams. This space, with the 29 ins. more to the buckle-plates, gave room enough for the work, and the staging still gave about 2 ft. more clearance than the High Street Viaduct, just east of it and over the same tracks. Fig. 4, Plate XVII, shows part of the north span of this viaduct, over the Cleveland, Cincinnati, Chicago and St. Louis Railway tracks. The portion of the three heavy trusses

above the pavement was in very fair condition, and it was not thought necessary to clean it with the sand-blast. This saved the cleaning of 36 000 sq. ft. of metal surface on this viaduct, while, on the others, practically all was cleaned. A portion of this viaduct, shown in Fig. 4, Plate XVI, is not over the railroad tracks, and was not affected as seriously as the remainder of the floor system. Some of the paint was still good, and it was not all taken off. This, together with the fact that there was not much interruption to the work, made the cost of cleaning, on this viaduct, less than on any other, all the others being much affected with rust, scale and corrosion upon nearly all parts of them, even above the level of the pavement, where protected from the direct action of the gases.

The south span of the High Street Viaduct, the portion already cleaned, is over the main freight and passenger tracks, and yard engines pass under it frequently. The other spans can be cleaned for very much less than this one. It has been estimated by men who are in the employ of the Pennsylvania Railway Company that an average of from 250 to 300 engines pass under this span every 24 hours. The girders and buckle-plates were in very bad condition, and very heavy and exceedingly firm scale had been formed over large portions of them. This scale was firmly cemented to the steel by the rust and carbonates which had formed. As a consequence, the sand-blast did not blow off much of it, nor did it work under the scale and throw it off, as on the other viaducts. Therefore, it cost nearly twice as much as the highest of the others, and nearly four times as much per square foot as the large Front Street Viaduct. The floor system is similar to that of the Maple Street Viaduct, the pavement being supported by seventeen plate girders. Immediately east of this is the structure under the roadway to the Union Station, also having seventeen plate girders. The distance over both is about 165 ft., and this, with the girders extending 3.5 ft. below the floor, causes the smoke to hang a long time between the girders after an engine has passed beneath. Often, it does not clear away before another engine comes along and again fills all the spaces with dense smoke. The smoke, and the dust from the sand-blast work, therefore, caused a great deal of trouble. It was very difficult, and part of the time impossible, to get nozzlemen to keep both blasts in operation. To get rid of the smoke and dust, an electric fan was tried for a short time, it being

placed near the abutment between the girders where the work was progressing. This kept the smoke from rising, and cleared away the dust quite well; but the bearings were injured very much by the dust and fine sand. Then the blower shown in Fig. 2, Plate XVI, was made. This was connected with the air pipe by a ½-in. rubber hose, and a jet of compressed air, passing through an opening of about $\frac{1}{32}$ in., and into and through a section of 5-in. sheet-iron pipe, about 2 ft. long, set up a current of air, which, being directed along between the girders, was quite effective. One of these was made for each sand-blast, and they were used for a considerable portion of the time. Smoke and dust, however, would gather behind the blower and be drawn through it at times, and it was not a complete success. It was effective for a distance of about 20 ft.

Another cause of the high cost of this work was the low pressure secured at the sand-blast machine during much of the time. The operation of the blowers tended to reduce it, and the compressor was worked beyond its intended capacity, and was not at the time doing as good work as earlier. The average pressure, at this viaduct, as stated in Table No. 1, is partly an estimate, as the gauge was broken and for a portion of the time was not in use. When at 30 lbs. or less, the sand-blast was very slow in cutting the scale here encountered; but when at 38 to 40 lbs., it was much more efficient. Occasionally, when only one blast was in operation for a short time, the pressure would run up to 45 lbs., and then the effect was still better.

From the experience in sand-blast cleaning here given it may be stated safely that, for heavy scale and corrosion, in situations such as this High Street Viaduct, a pressure of from 35 to 45 lbs. per square inch is not any too high. On the other hand, very efficient work is done at a pressure of about 25 lbs., where only light scale, rust spots and disintegrating paint are to be cleaned off. The labor costs approximately twice as much as the power, and increase of power is advisable where needed.

On all the cleaning done, the bright surface of the steel, having almost the appearance of frosted silver, was exposed to view by the removal of every vestige of rust, scale and old paint. The pitted portions, with a little more brushing, were as well covered with the paint as the others, and, after one year, it still holds on them as firmly, to all appearances, as when it first dried, after being put on.

The paint was applied very soon after the sand-blast, and sometimes curtains of heavy muslin were stretched between the painters and the sand-blast to prevent the dust and sand from interfering with the painting. All surfaces cleaned were painted before night, and rarely was it necessary for the painters to work more than half an hour after the sand-blast was discontinued for the day. It is best to work with the wind, so that it will carry the dust and sand away from the painters and nozzlemen.

Some records of actual results are shown in Table No, 2, both in the ordinary work of cleaning, and on tests in which an accurate account was taken for all the data presented therein. In some of these records there are omissions because all the elements were not noted. The long-time records give only the surface cleaned, and not the sand used or the horse-power necessary; and the two, showing results as to the whole work, are included for the sake of comparison. In these two are given some other results of calculations, from known quantities and records, which represent rates for one sand-blast, although two were running about 82% of the time. The number of hours stated is obtained by adding together the number of hours run by each machine. The tests of October 16th and 31st, 1902, were made in order to determine the relative effectiveness of nozzles of different diameters, from $\frac{1}{4}$ to $\frac{3}{4}$-in. in size. The sizes of pipe given are the nominal sizes of gas pipe, with "Ex. H." added where extra heavy gas pipe was used, which, of course, is smaller in interior diameter than standard gas pipe. The last one noted was with a nozzle (Fig. 3, Plate XVI), made from three $\frac{1}{4}$-in. gas pipes, one end of each being inserted in a $1\frac{1}{4} \times 1$-in. bushing, and babbitt metal poured in to secure them there. While only made for an experiment, this nozzle gave very good results, it having the highest rate of cleaning, in square feet per hour. It used considerable sand, about the same as the $\frac{3}{4}$-in. pipe, but cleaned nearly one-half more.

All these tests were made on the High Street Viaduct, where, for all of them, the corrosion was, as nearly as possible, of the same character. The rates of cleaning are low, because, on this viaduct, the scale was so hard. These tests of nozzles were made with a sand hose 65 ft. in length. All the nozzles for these eight tests were 12 ins. long. It will be seen from the results that the $\frac{1}{2}$-in. extra heavy pipe, which is $\frac{3}{4}$ in. when worn out, is about the proper size for this kind of work.

TABLE No. 2.—Data as to the Operation of the Sand-Blast; and Tests of Nozzles of Different Diameters, at Columbus, Ohio.

Date.	Duration.		Nominal size of gas pipe nozzle.	Air Pressure.		Cubic feet of free air per minute.	Horse-power required.	Cubic feet of sand used.	Area cleaned, in square feet.	Square feet cleaned per cubic foot of sand.	Rates per Hour.		Remarks.
	Hours.	Minutes.		At compressor.	At sand-blast.						Cubic feet of sand.	Square feet cleaned.	
1899.													
Sept. 27.....	....	29	½"	..	35	170	20.4	1.52	110	72.5	3.14	227.6	Pittsburg, Cincinnati, Chicago and St. Louis Railway work.
1901.													
Nov. 14.....	....	55	½" Ex. H.	50	35	170	20.4	6.60	144	21.8	7.20	157.1	Plate girder, considerably rusted
" 16.....	....	26	½" Ex. H.	50	36	...	....	2.20	77	35.0	5.10	177.7	Plate girder, paint nearly destroyed.
" 14.....	4	45	½" Ex. H.	50	35	170	20.4	.....	375	....	....	79.0	Plate girder (includes lost time).
" 16.....	3	..	½" Ex. H.	50	36	...	....	.....	322	....	....	107.3	Plate girder, paint nearly destroyed (includes lost time).
" 18.....	7	50	½" Ex. H.	50	36	...	....	.....	655	....	....	83.6	Plate girder, paint nearly destroyed (includes lost time).
" 19.....	7	30	½" Ex. H.	50	35	...	....	.....	825	....	....	110.0	Plate girder, paint nearly destroyed (includes lost time).
" 20.....	7	30	½" Ex. H.	40	25	...	....	.....	1 227	....	....	164.0	About 10% of paint good and not removed (includes lost time).
Dec. 7.....	13	30	½" Ex. H.	48	33	...	....	.....	1 000	....	....	74.1	Floor system over railroad tracks (includes lost time).
Nov. 14th, 1901, to Aug. 13th, 1902...	1 519	..	½" Ex. H.	..	33	...	....	5 658.9	112 900	20.0	3.72	74.3	First four viaducts in Table No. 1.
1902.													
Aug. to Nov..	990	..	½" Ex. H.	..	33	...	....	3 507.6	22 600	6.4	3.54	22.8	High Street Viaduct, see Table No. 1.
Oct. 16.....	....	18	½" Ex. H.	55	37	156	18.7	1.40	11.80	8.4	4.67	39.33	High Street Viaduct, test run.
" 16.....	....	24	½"	55	37	140	16.8	1.31	6.65	5.1	3.28	16.63	High Street Viaduct, test run.
" 16.....	....	27½	½"	55	39	108	13.0	1.20	2.42	2.0	2.62	5.28	High Street Viaduct, test run.
" 20.....	....	27	½" Ex. H.	..	35	...	....	3.30	18.70	5.4	7.67	41.60	High Street Viaduct (another blast running).
" 31.....	....	7¼	½"	55	40	200	24.0	1.10	4.25	3.9	9.10	35.20	High Street Viaduct, test run.
" 31.....	....	18	½" Ex. H.	55	41	170	20.4	2.20	14.00	6.4	7.33	46.67	High Street Viaduct, test run.
" 31.....	....	9	½"	55	42	156	18.7	1.10	6.60	6.0	7.33	44.00	High Street Viaduct, test run.
" 31.....	....	24	½"	55	43	130	15.6	1.00	4.75	4.7	2.50	11.88	High Street Viaduct, test run.
" 31.....	....	7	¾"	55	41	176	21.1	1.10	6.60	5.4	9.43	51.40	High Street Viaduct, test run.

Improvements can certainly be made in this apparatus. Some of the appliances were made as experiments, and are rather crude. One observation may be made which will occur to all, that more sand-blasts might be added with advantage, if sufficient power to run them were provided. The work at Columbus was limited to two machines, on account of the small capacity of the compressor. Perhaps a larger pipe to convey the air would have added to the pressure at the machines, and to the effectiveness of the sand-blast. For ordinary cleaning of bridges and other structures, not subjected to such hard treatment as viaducts situated where much exposed to the blast and gases from locomotives, it is safe to say that, with a more perfect equipment, sand-blast cleaning can be done at from 1¼ to 2 cents per square foot. The advantages anticipated for this kind of cleaning, especially where almost a necessity, because nothing else will do the work thoroughly, are to be gained by a careful inspection at intervals after it is done, and the repainting, with ordinary, good hand-cleaning, before the paint has been worn off so as to set up the vigorous rusting process which comes when air and moisture get to the metal. In such locations as the viaducts in Columbus it seems to be the only thing that will do the work. For future construction in similar locations let every engineer beware of the use of steel exposed to locomotive blasts, as these will wear out any paint. The life of those structures already in existence, and others which may be built in the future, should be extended as long as possible by the use of the best means that can be commanded.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE FILTRATION WORKS OF THE EAST JERSEY WATER COMPANY, AT LITTLE FALLS, NEW JERSEY.

By GEORGE W. FULLER, Assoc. M. Am. Soc. C. E.

TO BE PRESENTED APRIL 1ST, 1903.

HISTORICAL.

The East Jersey Water Company, in 1897, commenced the development of a new source of supply from the Passaic River, at Little Falls, N. J., about 5 miles above Paterson. The pumping station, which was completed in the autumn of 1899, has a capacity of 75 000 000 galls. daily. It is a combination water- and steam-power plant, the pumps being placed between the turbines and steam engines, and connected so that either water or steam power, or both, may be used.

At present, an average daily quantity of about 50 000 000 galls. of water is pumped at this station. Approximately, this quantity has been pumped regularly since November, 1899, and supplied to cities having an aggregate population of about 450 000. About 30 000 000 galls. daily are supplied to Jersey City, in accordance with a temporary contract with the Water Company which terminates at the end of 1903, following the completion of the new gravity water supply now

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

being constructed for that city on the Rockaway River, near Boonton, N. J. About 15 000 000 galls. daily are supplied from this station to the cities of Paterson and Passaic. At the close of the Jersey City contract, filtered water from Little Falls will be supplied, to several towns and water companies, through the conduit now used to deliver river water to Jersey City. Among these consumers are Montclair, West Orange and Glen Ridge, which now receive their supply from the surplus of the Pequannock system, in accordance with arrangements made by the East Jersey Water Company with the City of Newark. After the present year, in the neighborhood of 25 000 000 galls. of filtered water daily will probably be furnished from Little Falls.

The water-shed of the Passaic River, at Little Falls, has an area of 772 sq. miles. A large part of two important tributaries of the Passaic is already appropriated for municipal supplies, namely, 63 sq. miles of drainage area of the Pequannock River, which is the source of supply of the City of Newark, and 118 sq. miles on the Rockaway River, above the intake for the works now being built for Jersey City. Some of the more important features of interest in connection with the Passaic water-shed are indicated in Fig. 1.

There are no towns or cities discharging sewage into the Passaic River within some 20 miles of the intake at Little Falls. The only places on the water-shed having sewerage systems are Suffern and Summit, the sewage of the latter being filtered before it reaches the river. There are, however, quite a number of towns and small cities, including Chatham, Madison, Morristown, Boonton and Dover, where there are public water supplies, and where some sewage may reach the stream indirectly, especially following heavy rains.

In its sanitary character the water of the Passaic River at Little Falls is ordinarily very satisfactory, as is shown by numerous analyses and by the typhoid-fever records of the communities which have been supplied with that water during the past three years. The average annual death rate from typhoid fever during the past three years, in Jersey City, Paterson, Bayonne and Passaic, is about 20 per 100 000 inhabitants, and in no case has it exceeded 23 for a single year.

The Passaic River water at Little Falls is not muddy, comparatively speaking, although, after heavy freshets, it carries from 25 to 100 parts per million of suspended matter. At times the water is very noticeably colored, due to dissolved vegetable matter coming from

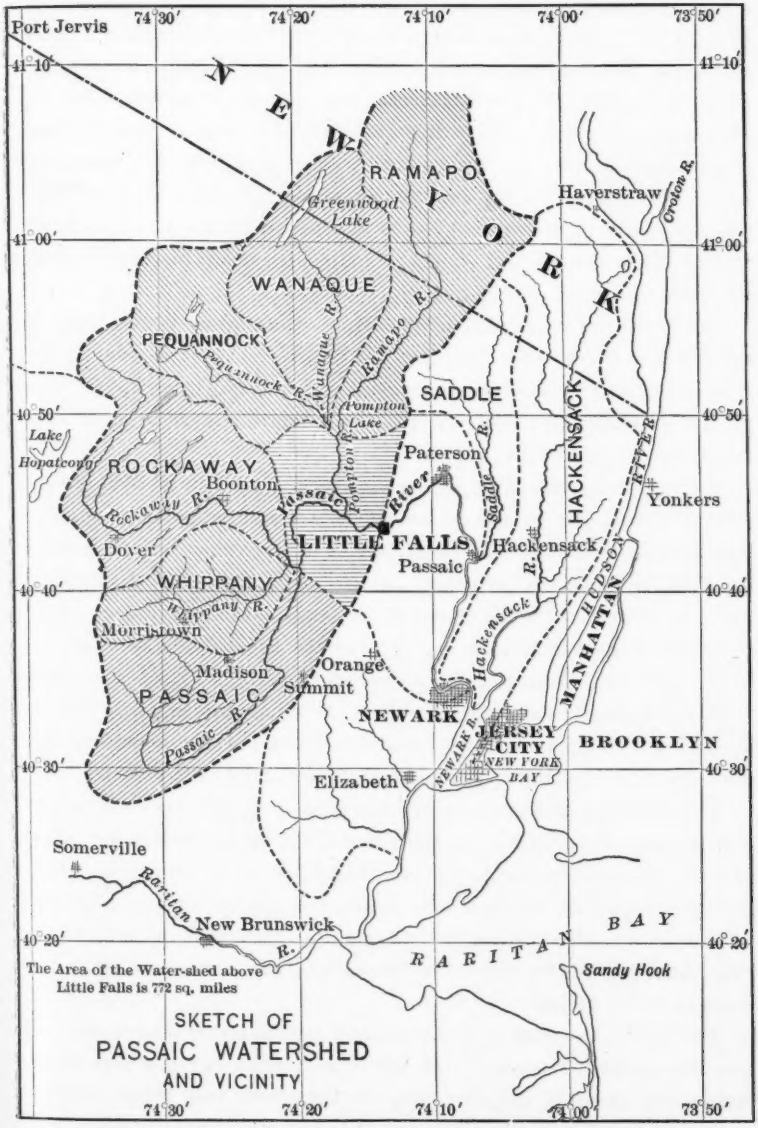

Port Jervis
74°30′
74°20′
74°10′
74°00′
73°50′
41°10′
41°00′
40°50′
40°40′
40°30′
40°20′
NEW YORK
RAMAPO
Greenwood Lake
Haverstraw
Croton R.
WANAQUE
PEQUANNOCK
Pequannock R.
Wanaque R.
Ramapo R.
Pompton Lake
SADDLE
Lake Hopatcong
ROCKAWAY
Boonton
Rockaway R.
Passaic R.
Pompton R.
Saddle R.
Paterson
HACKENSACK R.
Yonkers
Dover
LITTLE FALLS
Hackensack
Passaic
WHIPPANY
Whippany R.
Morristown
Madison
Orange
Summit
PASSAIC
Passaic R.
Hackensack R.
HUDSON R.
MANHATTAN
NEWARK
JERSEY CITY
BROOKLYN
Newark R.
NEW YORK BAY
Elizabeth
Somerville
Raritan R.
New Brunswick
RARITAN BAY
Sandy Hook
The Area of the Water-shed above Little Falls is 772 sq. miles
SKETCH OF
PASSAIC WATERSHED
AND VICINITY

FIG. 1.

several large swamps situated on the upper portions of the drainage area. Frequently, the water contains quite large amounts of amorphous matter, consisting principally of finely divided organic material. Much of this seems to come from the bottom of the stream, as the water flows for a few miles through the Great Piece Meadows, just above the intake, where the river has very little slope and where deposited sediment on the bottom is stirred up by carp and other fish. This finely divided amorphous matter, together with the color which appears in the water, gives it at times what might be called a "dirty" appearance, and causes it to be less desirable for domestic use than the analyses indicate.

With the view of making the water thoroughly satisfactory in appearance, and to guard against the effect of the accidental pollution which may be possible occasionally, the Water Company investigated the feasibility of filtration works. A preliminary report on the subject was made by the writer in May, 1900.

Before considering this matter in detail, it will be well to give a general description of the pumping station and immediate vicinity. The pumping station was described in *Engineering News* of August 3d, 1899, in which the principal details may be found. In brief, it may be said that the river water, for both power and water-supply purposes, is conveyed from the river above the Beattie Dam to the intake gate-house near the pumping station through a head-race canal, 1 400 ft. in length and 60 ft. in width. It terminates in a fore-bay, at the side of which is a spillway, and at the end are the penstocks and other conduits leading to the turbine wheels and to the pumps.

The elevation of the water in the head-race canal is normally about 157. In the river below it averages about 122, giving, ordinarily, a fall of about 35 ft. for power purposes. The floor of the pumping station is at Elevation 132, which is also the elevation of the suction chamber of the pumps. To the north of the pumping station is a cliff of trap rock overlying brown stone, the elevation of the surface being in the neighborhood of 180.

The site of the pumping station and power-house was reclaimed from the original river-bed. As will be seen from Fig. 2, a plan of the station and grounds, the river turns to the north just below, leaving an area of less than 2 acres between the river and the force mains, the elevation of the surface of which was in the neighborhood of 130.

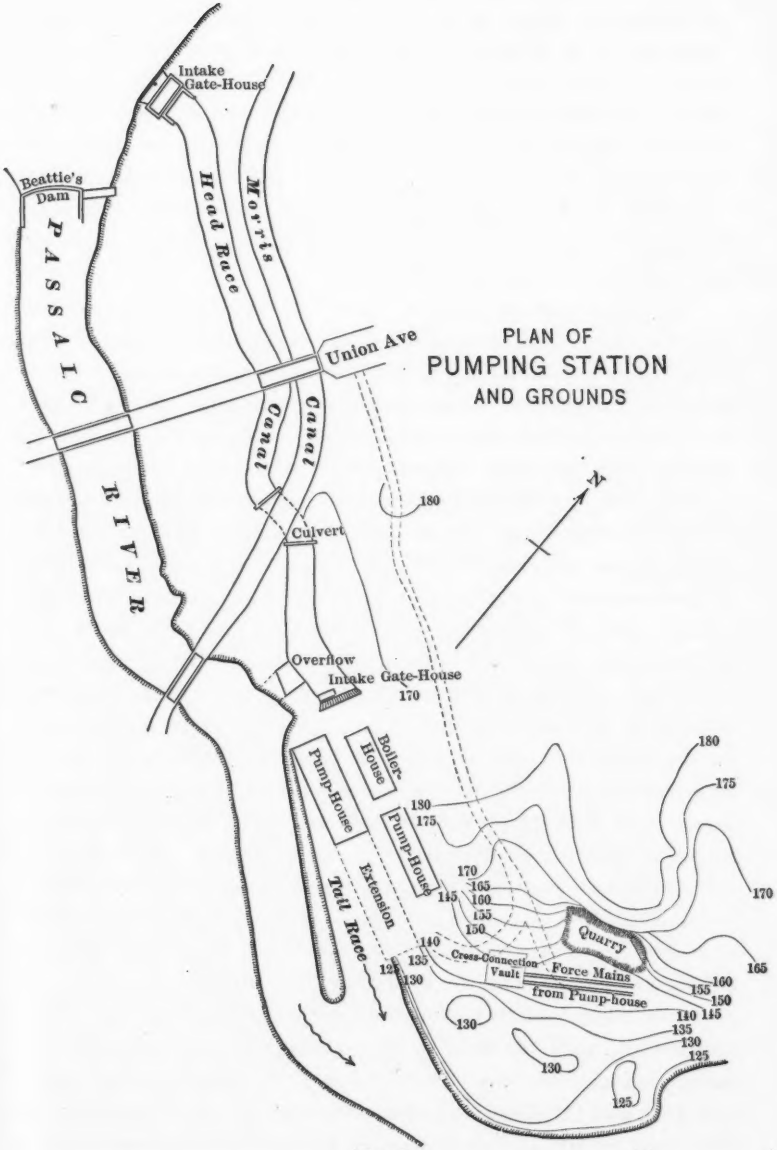

PLAN OF
PUMPING STATION
AND GROUNDS
Intake Gate-House
Beattie's Dam
PASSAIC RIVER
Head Race
Morris Canal
Union Ave
Culvert
Overflow
Intake Gate-House
Boiler-House
Pump-House
Pump-House
Tail Race Extension
Quarry
Cross-Connection Vault
Force Mains from Pump-house
180
175
170
165
160
155
150
145
140
135
130
125

FIG. 2.

It was recommended that the filtration works be of the American, or mechanical, type, partly on account of the great desirability of removing the high amount of color which the river water possesses at times, and especially on grounds of economy. It was possible to construct a mechanical filter plant on the small area of ground below the pumping station, through which water might pass by gravity from the head-race canal and back to the suction of the main pumps. If a sand-filter plant had been installed, it would have involved the expense of an additional pumping station to lift the river water to a suitable site upon the cliff above.

The Water Company, in June, 1900, requested the New York Filter Manufacturing Company and the Continental Filter Company, shortly afterward consolidated as the New York Continental Jewell Filtration Company, to submit outline plans and general estimates of cost for this project. These were submitted to the Water Company in September, 1900, and were referred to the writer, who was requested to supervise for the Water Company the preparation of detailed plans by the Filtration Company, and also to prepare specifications. It is gratifying to record that the Water Company instructed the writer not to spare expense in making the plant capable of giving thoroughly efficient service. Mr. Charles L. Parmelee, Chief Engineer of the Filtration Company, had the immediate charge of the preparation of the plans. Upon their construction features the writer had the assistance of W. B. Fuller, M. Am. Soc. C. E., who, later, was appointed by the Water Company as Resident Engineer in charge of the construction work. The entire project was designed and built under the direction of J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer and Superintendent of the East Jersey Water Company. With the exception of the machinery and the operating devices, which were designed by the Filtration Company, the design of this plant was the result of numerous conferences and discussions between the representatives of the Water Company and the Filtration Company.

These works, with few exceptions, were built by contract. All excavation and masonry work in the coagulating basin and clear-water basin, grading, etc., was done by the T. A. Gillespie Company, of New York and Pittsburg; the filter tanks and the entire superstructure were built by Mr. Joseph Sharpe, of Paterson sub-contractor under he Gillespie Company; and the entire equipment of the filters, includ-

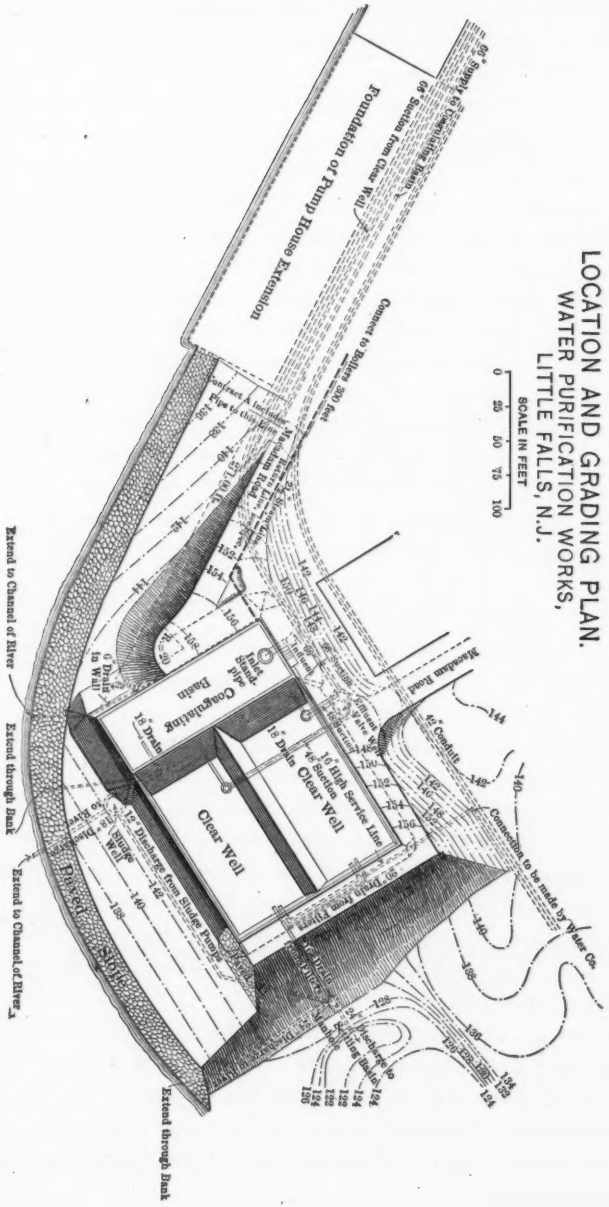

LOCATION AND GRADING PLAN.
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.
SCALE IN FEET
0 25 50 75 100
Foundation of Pump House Extension
Coagulating Basin
Clear Well
Meadow Road
Connection to be made by Water Co.
Extend to Channel of River
Extend through Bank
Extend to Channel of River
Extend through Bank

Fig. 3.

ing piping, valves, strainer systems, machinery and devices for applying the coagulant and operating the filters, was furnished and erected by the Filtration Company.

Construction work was begun early in April, 1901, and at the end of that year all masonry work, pipes within the walls of the coagulating basin and the clear-water basin, the filter tanks, and the floor of the superstructure, were completed. The walls of the superstructure were barely started. The completion of the buildings proceeded very slowly, due to several interruptions by strikes, etc., and it was not until May, 1902, that the Filtration Company commenced the equipment of the filters. The latter was practically completed by August 1st, 1902; but, owing to delays in securing filter sand, the plant was not placed in service until September 4th, 1902. Since that date the filters in the north wing have been in service regularly, and no unfiltered water has been delivered to consumers in Paterson or Passaic.

The filters in the south wing have not been placed in service, and will not be until after the termination of the temporary contract with Jersey City.

General Description of the Filtration Works.

These filtration works, which have a nominal net capacity of 32 000 000 galls. daily, and are capable, at least for short periods, of yielding 48 000 000 galls. daily, occupy an area of 178 x 219 ft., measured on the outside lines of the foundation walls. The structures are of concrete, with the foundations upon rock at an average elevation of 114. As the flow line in the coagulating basin and in the filters is but a little less than that in the head-race canal (157), it is seen that the structures are relatively very deep, owing to the peculiarities of the site. Views of the works are shown in Plate XVIII.

At the west end is the coagulating and subsiding basin, 130 ft. long, 42 ft. wide and 43 ft. deep on inside lines, having a capacity of about 1 750 000 galls.

At the east end the lower portion of the structure contains a clear-water basin in two compartments. Each, on an average, is 124 ft. long, 58 ft. wide and 29 ft. deep to the maximum flow line for the filtered water. The total capacity of the clear-water basin is about 3 500 000 galls. Fig. 3 is a general plan of the coagulating basin and clear-water basin.

Fig. 4.

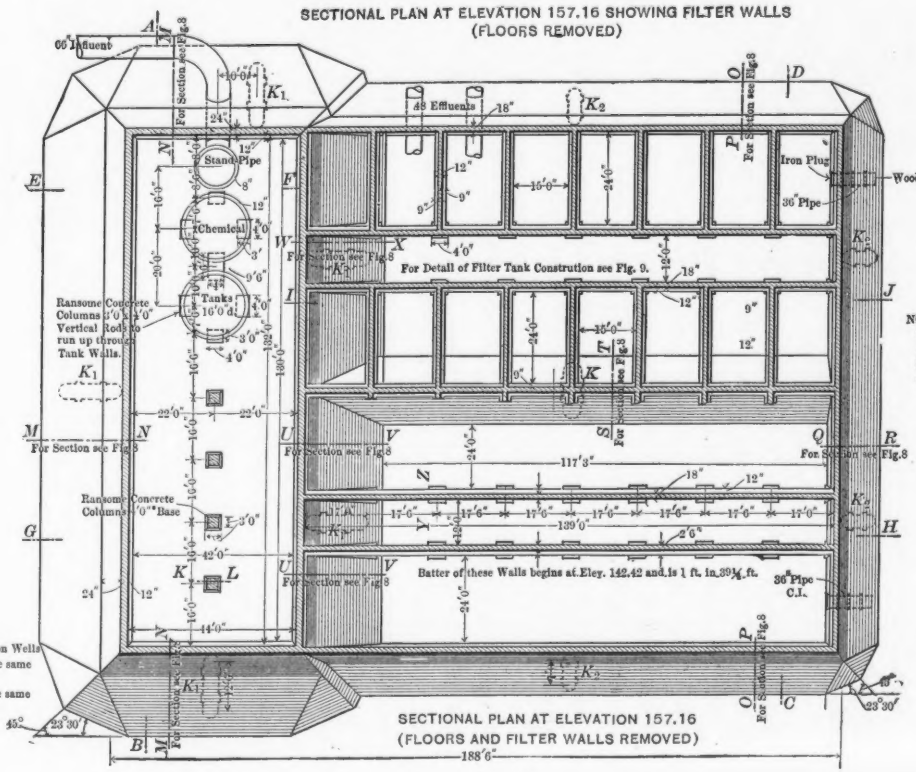

SECTIONAL PLAN AT ELEVATION 157.16 SHOWING FILTER WALLS
(FLOORS REMOVED)
66" Influent
For Section see Fig. 8
48 Effluents
Stand Pipe
Chemical Tanks 16'0" dia.
Ransome Concrete Columns 3'0" x 3'0" Vertical Rods to run up through Tank Walls.
Ransome Concrete Columns 3'0" Base
For Detail of Filter Tank Construction see Fig. 9.
Iron Plug
Wooden Plug
36" Pipe
36" Pipe C.I.
Batter of these Walls begins at Eley. 142.42 and is 1 ft. in 39¼ ft.
NOTE:
The Outer Toes of all Walls and Posts are shown approximately only. Their exact position depends upon the elevation of the Rock.
NOTE:
K-K are Expansion Walls
All K1 Walls have same dimensions.
All K2 Walls have same dimensions.
SECTIONAL PLAN AT ELEVATION 157.16
(FLOORS AND FILTER WALLS REMOVED)
188'6"
GENERAL PLAN OF SUBSTRUCTURE

FIG. 4.

Above the clear-water basin there are thirty-two rectangular concrete filter tanks, 24 x 15 ft., and 8 ft. deep, arranged in four rows of eight filters each. The total area of filtering surface is 11 520 sq. ft. Between each pair of rows of filters there is a pipe gallery, in which the main pipes, with branches to the adjoining filters, are placed. This gallery is about 12 ft. wide and 13.5 ft. high, inside. The ends of the filter tanks form the upper portion of the walls of the galleries. The lower portion is formed by walls which extend to the bottom of the clear-water basin, and form a support for the filter floors. The lower portion of these walls is arched out. A sectional plan and cross-sections of the substructure are shown in Figs. 4 and 5.

Over each pipe gallery there is a platform, at a level slightly above that of the water in the filter tanks, and on which the attendants stand when operating the filters. Over each of these platforms, and extending for a width of about 6 ft. on either side, is a building. These two buildings, each about 140 x 30 ft., are called the filter houses, and form two wings of the main building, with which they connect. The remaining portion of the filters is covered with a flat concrete roof with a manhole over each filter, through which materials may be added or removed.

The coagulating basin is covered with a flat concrete roof, which forms the floor of the main building. This building is 132 x 46 ft., and contains the machinery-room for the rotary blowers, pumps and devices for applying coagulant, storage for the same, and also the laboratories, offices, tool-room, wash-rooms, lockers, etc. Figs. 6 and 7 show a plan and section of the buildings.

All machinery is operated by electric motors, the current for which, as well as for the electric lights, is furnished by generators located in the main pump-house.

River water is taken from the head-race canal, and is delivered to the filtration works through a 66-in. steel main discharging into a concrete stand-pipe, 10 ft. in diameter, located at the north end of the coagulating basin. In this stand-pipe the water is treated with a solution of coagulant, and, after thorough mixing by the natural agitation in the stand-pipe, it passes from the bottom of the same into the coagulating basin and thence to the south end, where, near the surface, it is collected in a perforated pipe, through which it passes to the filters. It is possible to by-pass the coagulating basin,

LONGITUDINAL SECTION ON G-H

Fig. 5.

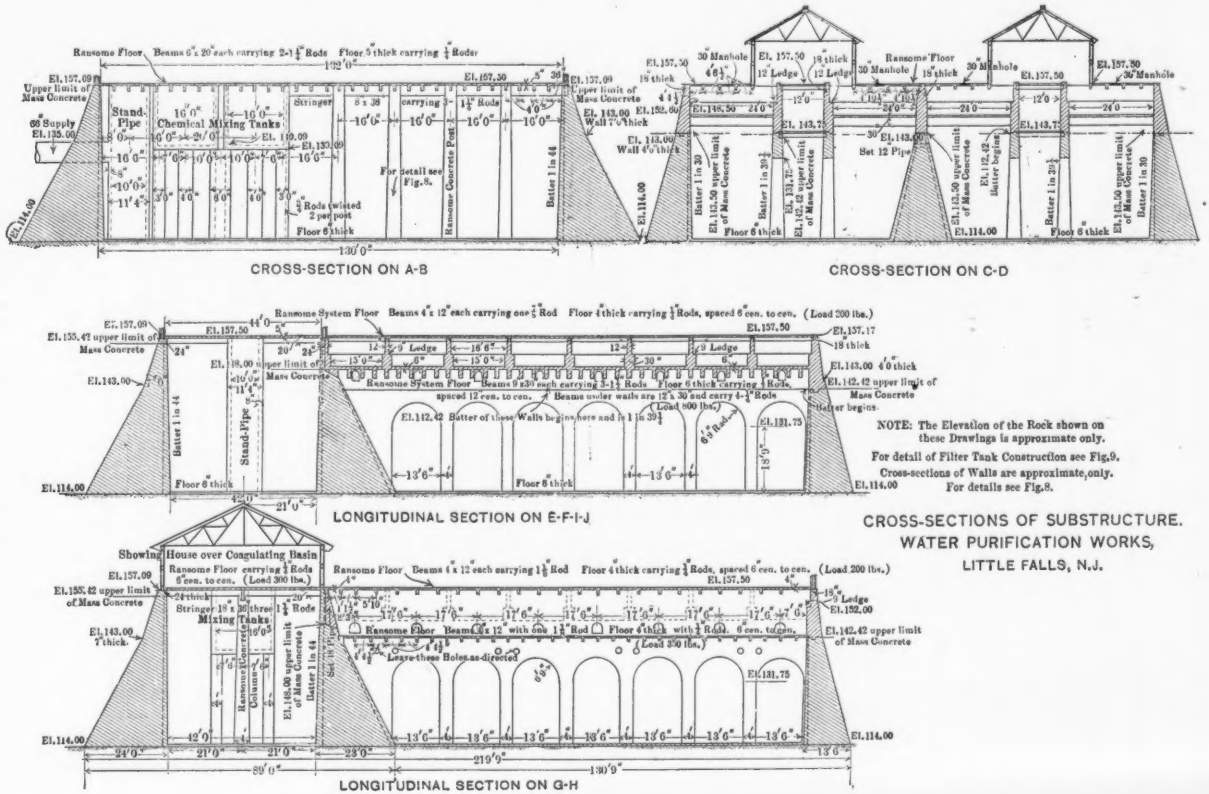

CROSS-SECTION ON A-B
CROSS-SECTION ON C-D
LONGITUDINAL SECTION ON E-F-I-J
LONGITUDINAL SECTION ON G-H
NOTE: The Elevation of the Rock shown on these Drawings is approximate only.
For detail of Filter Tank Construction see Fig. 9.
Cross-sections of Walls are approximate only.
For details see Fig. 8.
CROSS-SECTIONS OF SUBSTRUCTURE.
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.

FIG. 5.

and deliver the water from the upper portion of the stand-pipe through a pipe connecting with the main inlet pipes to the filters. After passing through the filters the water enters the clear-water basin, from which it flows through a 66-in. steel suction main, encased in concrete and leading to the main pumps. Branch suction pipes extend from the sump in either compartment of the clear-water basin, with necessary valves in an effluent-valve well, located outside the basin where the branches join the main line. Filtered water from the entire plant may be taken from either compartment independently of the other.

Necessary facilities are also provided for cleaning out the coagulating basin, including a pump located in a sludge well to the south of the basin. Arrangements are made by which at times of low water, if need be, the sediment removed from the basin, as well as that from the discharged wash-water, may be settled out in a catch-basin to the east of the filter plant. The main features of the outside piping are shown in Fig. 3.

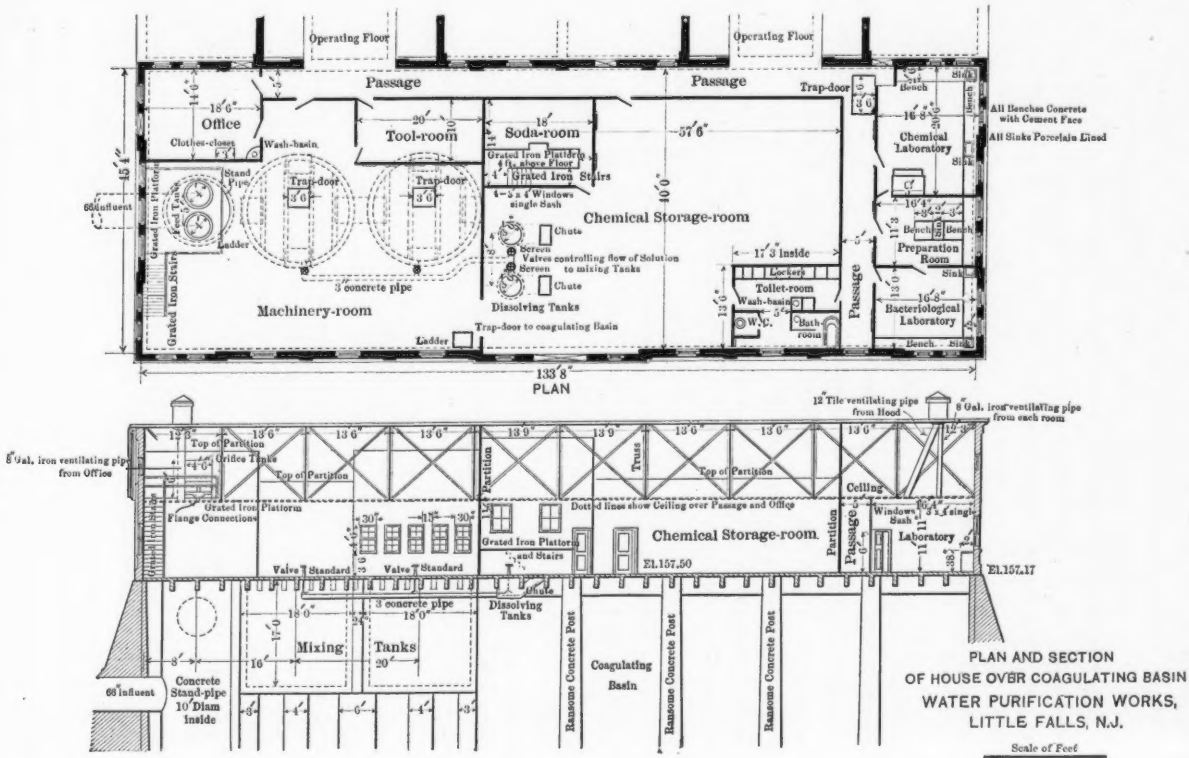
General Features of Construction.

The coagulating basin and clear-water basin are of concrete. Reinforced concrete, after the Ransome system, was used for the construction of the filter tanks, all floors and walls of the houses, and the roof of the filter tanks. No wood was used about the buildings, except in the doors and windows.

The mass concrete in the main walls of the substructure was mixed in the proportion of 1 : 3 : 7. Atlas cement, exclusively, was used for this portion of the work. The gravel and broken stone were graded with much care, the general range in size being from ¼ in. to 3 ins. in diameter. The concrete was laid unusually wet. On the inside of the principal walls there is a facing of rich concrete mixed in the proportions of 1 : 1¼ : 3. Typical sections of the main walls are shown in Fig. 8.

In the main walls, as shown by dotted lines on Fig. 4, there were left seven expansion wells or openings, with the intention of having such cracks as might appear in the walls confined to these places, which, later, would be filled with concrete. A single crack developed at each of four of the wells.

The only crack of importance was one about ¼ in. in average


Operating Floor
Passage
Office
Clothes-closet
Wash-basin
Tool-room
Soda-room
Grated Iron Platform 6 ft. above Floor
Grated Iron Stairs
4–5 x 4 Windows single Sash
Chemical Storage-room
Chute
Screen
Valves controlling flow of Solution to mixing Tanks
Dissolving Tanks
Trap-door to coagulating Basin
Ladder
Stand Pipe
Trap-door
3 concrete pipe
Machinery-room
Grated Iron Platform
Grated Iron Stairs
66 Influent
Trap-door
Chemical Laboratory
All Benches Concrete with Cement Face
All Sinks Porcelain Lined
Preparation Room
Bacteriological Laboratory
Toilet-room
Wash-basin
W.C.
Bath room
Lockers
Passage
133' 8"
PLAN
12" Tile ventilating pipe from Hood
8" Gal. iron ventilating pipe from each room
8" Gal. iron ventilating pipe from Office
Top of Partition
Orifice Tanks
Flange Connections
Grated Iron Platform
Partition
Truss
Ceiling
Dotted lines show Ceiling over Passage and Office
Windows Sash
Laboratory
Chemical Storage-room
Grated Iron Platform and Stairs
El. 157.50
El. 157.17
Valve
Standard
Chute
Dissolving Tanks
3 concrete pipe
Mixing
Tanks
Ransome Concrete Post
Coagulating Basin
66 Influent
Concrete Stand-pipe 10' Diam Inside
PLAN AND SECTION
OF HOUSE OVER COAGULATING BASIN
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.
Scale of Feet
0 5 10 15 20

FIGS. 6 AND 7.

width, which extended through the expansion well of the division wall in the clear-water basin, across the floor of the south basin and part way up the outer wall of the latter at the expansion well. This was repaired before water was turned on, and no leaks of consequence were detected in any of the walls of the coagulating basin or clear-water basin when the plant was placed in service. In fact, appreciable amounts of moisture on the outside of the walls were noticeable in only two or three instances.

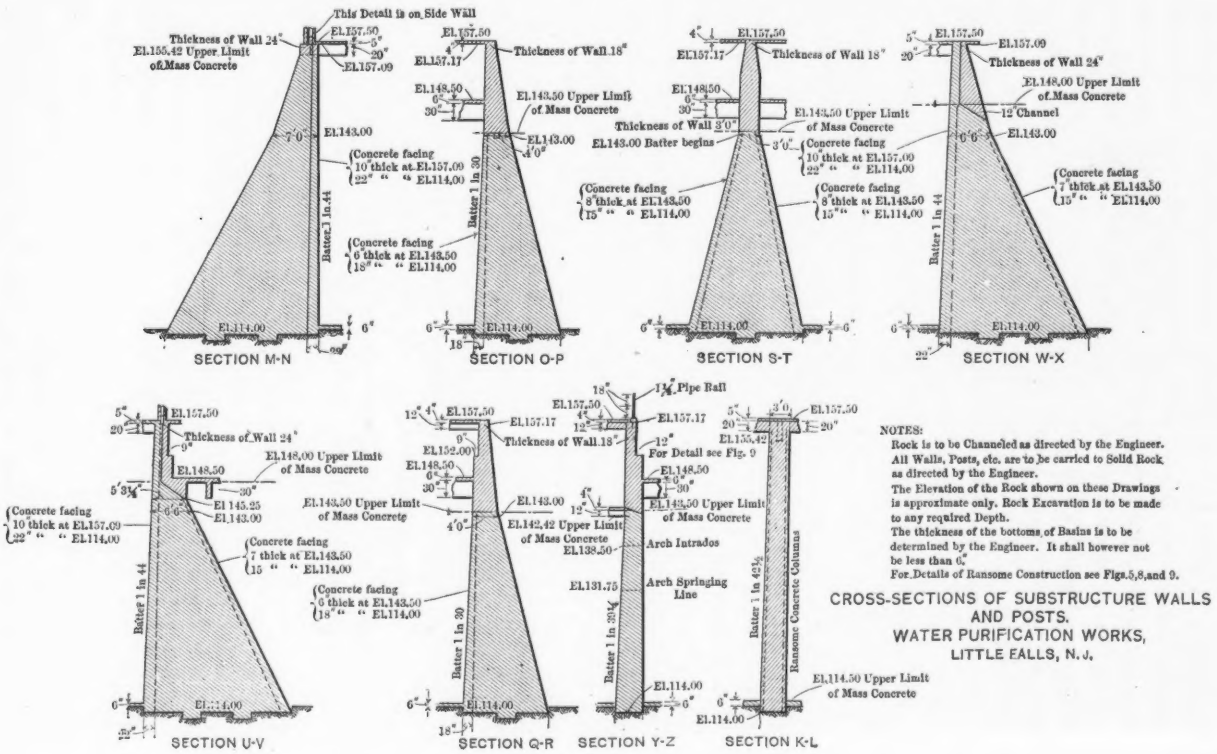
Upon emptying the basins during the past month no cracks were detected in the walls of the coagulating basin, but a very narrow crack was noted opposite the expansion well in the wall separating the coagulating basin from the south compartment of the clear-water basin. It extends some 20 ft. from the bottom, and, under a head of about 40 ft., water was oozing from the lower end at the rate of about ½ gall. per minute.

Each filter tank, 15 x 24 ft. and 8 ft. deep, was built as a continuous box of concrete reinforced with twisted steel roads in each direction, placed as shown in Fig. 9. It was specified that each of these filter tanks when started should be built continuously until completed. The concrete used in these tanks was mixed in the proportions of about 1 : 2 : 4, and was laid very wet. Vulcanite cement was used principally for this portion of the work. All the filter tanks were plastered on the inside with a ¼-in. coat of rich mortar, in the proportions of 1 part of cement to 1 part of sand. The inner walls of the tanks below the sand surface were roughened by stippling with a wire brush before the plastered surface had thoroughly set. In no instance have there been any cracks or leaks in these filter tanks.

The concrete roof over the filters, which was built as a part of each respective tank, is 4 ins. thick, supported by Ransome concrete beams 4 x 12 ins., placed 54½ ins. apart.

The floor of the main building, over the coagulating basin, has a thickness of 5 ins., with Ransome concrete beams spaced 4 ft. apart. One end of each beam is supported by the walls of the basin and the other by a central Ransome concrete girder, 8 x 36 ins., with three 1¼-in. rods. This girder is supported by Ransome concrete columns, 4 ft. square at the base and 43 ft. high.

The tanks for preparing solutions of sulphate of alumina, of which there are two, each 17 ft. deep and 16 ft. in diameter, are built of Ran-



NOTES:
Rock is to be Channeled as directed by the Engineer.
All Walls, Posts, etc. are to be carried to Solid Rock as directed by the Engineer.
The Elevation of the Rock shown on these Drawings is approximate only. Rock Excavation is to be made to any required Depth.
The thickness of the bottoms of Basins is to be determined by the Engineer. It shall however not be less than 6".
For Details of Ransome Construction see Figs. 5, 8, and 9.

CROSS-SECTIONS OF SUBSTRUCTURE WALLS AND POSTS.
WATER PURIFICATION WORKS,
LITTLE FALLS, N. J.

FIG. 8.

some concrete, and are placed beneath the floor of the main house.

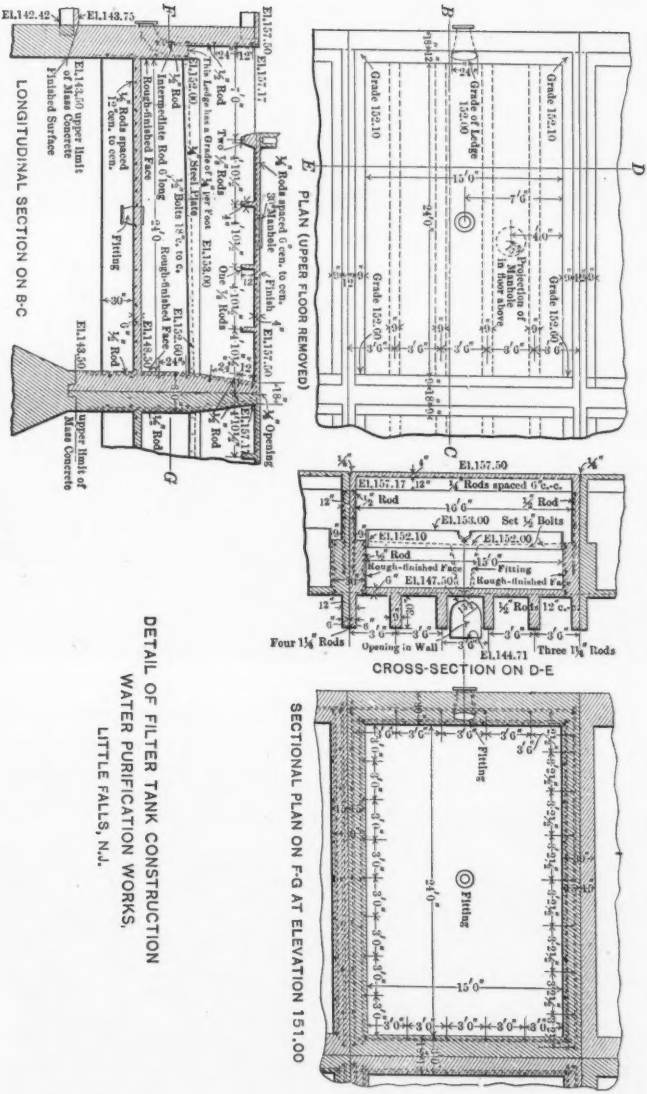
The main house over the coagulating basin, about 46 ft. wide and 132 ft. long, has hollow concrete walls 13 ft. high. The slate and tile roof is supported by steel trusses. The two filter houses, forming wings to the main house, are also built with hollow concrete walls. In order to make the buildings harmonize with the pump-house, the cement was colored to resemble brown stone.

Expansion joints in the walls of the buildings were provided, back of each pilaster, with the view of preventing cracks. Very few cracks have appeared elsewhere.

Regarding the specifications, it may be of interest to state that the Water Company furnished the cement for the substructures, which were built strictly in accordance with the plans, the Water Company taking full responsibility as to stability and water-tightness. The superstructure, including all tanks, was built under a guaranty in these respects. The contractor furnished the cement, and had the option of increasing the quantities of concrete and metal above those shown in the plans, which were the minimum permitted by the Water Company. The guaranteed safe loads per square foot were: 800 lbs. for the floor of the filter tanks, 200 lbs. for the roof of the filters, 350 lbs. for the floor of the pipe gallery, 200 lbs. for the operating platform, and 300 lbs. for the floor of the main building. As to the filter equipment, the Filtration Company guaranteed specified efficiencies for the machinery, and that all devices should perform successfully the work for which they were designed, when judged from a strictly physical or mechanical standpoint. The Water Company took full responsibility as to the behavior of the plant in treating the water.

Description of the Details of the Principal Devices.

Application of Coagulant.—Sulphate of alumina is used as the coagulating chemical. It is received in barrels in carload lots, and stored in the main building. The dry chemical is weighed and dumped into the chutes leading to the dissolving tanks situated below the floor in the store-room. In these tanks saturated solutions are prepared, and, to accelerate the dissolving action, heavy bronze stirrers are provided, which revolve slowly in the mass of chemical in the tanks. From these dissolving tanks, each of which has a capacity of 252 galls., the solutions flow through cement pipes to the mixing



DETAIL OF FILTER TANK CONSTRUCTION
WATER PURIFICATION WORKS.
LITTLE FALLS, N.J.

FIG. 9.

tanks. These are of concrete, circular in plan, 17 ft. deep, and each holding about 25 000 galls. The saturated solutions are here diluted to any desired degree by the addition of filtered water. Uniformity in strength of solutions is maintained by frequent stirring by air agitation, the air being supplied from rotary, belt-driven blowers, about 75 cu. ft. of free air per minute being distributed through a radial system of air-pipes at the bottom of each tank.

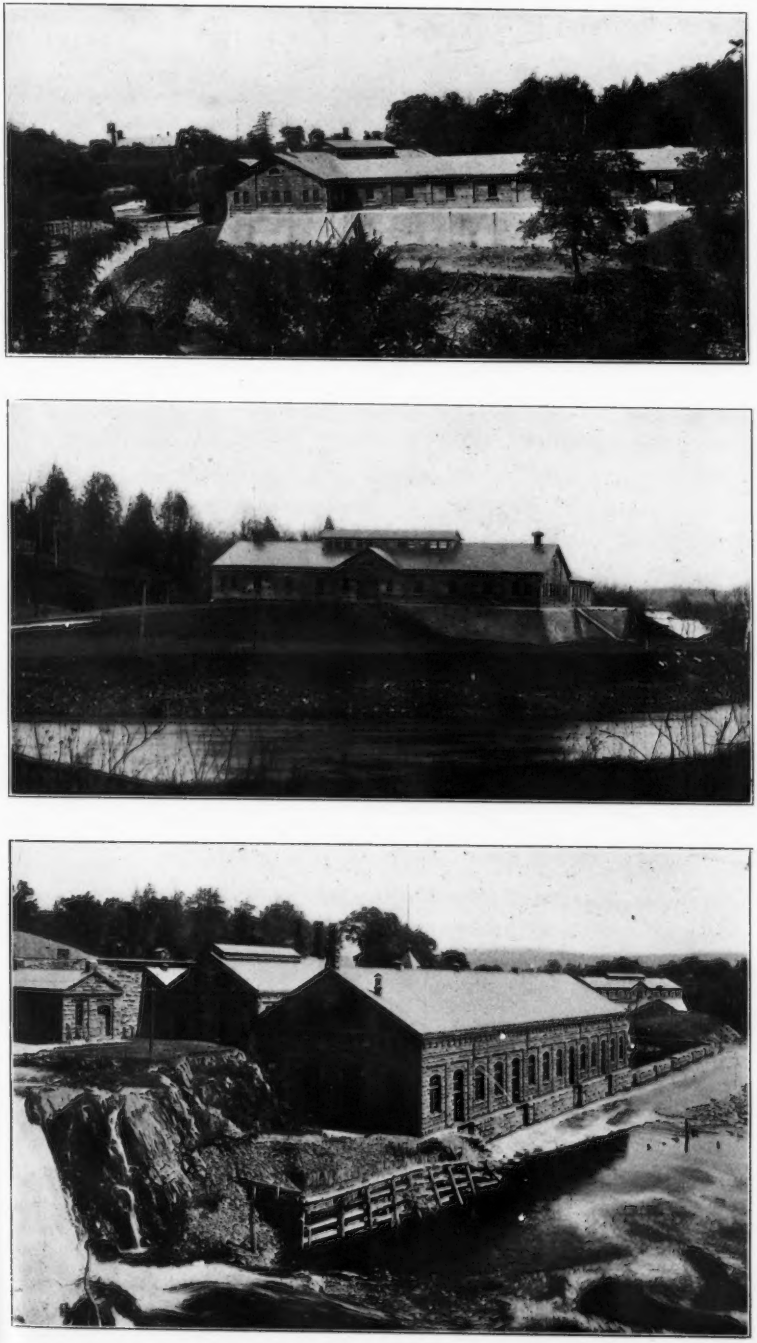
The solutions are lifted from the mixing tanks, by centrifugal pumps, to the orifice tanks, which are in duplicate, built of concrete, 4 ft. in diameter, of a capacity of 340 galls. each, and situated on a platform in the machinery-room, with the flow line at Elevation 170, or about 13 ft. above the water line of the coagulating basin.

The centrifugal pumps are of standard pattern, cast of special bronze, and are operated by direct-connected electric motors. All pipes, valves and fittings are of hard rubber. All devices are in duplicate, only one set being used at a time.

The quantity of solution pumped from the mixing tanks to the orifice tank may be regulated in the latter, approximately, by a piston valve operated by a float, but it is always kept slightly in excess of the amount being used, and there is an overflow pipe through which the excess is returned to the mixing tank. In this way there is maintained a constant level in the orifice tank, and hence a constant head on the orifice through which the solution passes from the elevated tank to the raw river water.

As the solution leaves the orifice tank it flows into a concrete funnel on the mouth of a 2-in. pipe, which conveys it to the discharge manifold. The latter is located in the mouth of the main inlet pipe, and is a wrought-iron frame holding a grid of ½-in. brass pipes tapped into a 2-in. brass header. The branches are 6 ins. apart, and each one has ¼-in. holes, on 6-in. centers, through which the coagulant solution is discharged. The total number of holes in this discharge manifold is 100. The manifold is hung in vertical slides from the stand-pipe, and can be raised or lowered readily by means of wire ropes and a windlass.

Regulation of Coagulant Feed.—At the bottom of the orifice tank there is a rectangular slot, made of hard rubber and having a fixed width of ¼ in. By means of a slide, which works over the face of this orifice, the length of this opening may be adjusted from 0 to 6 ins.



PUMPING STATION AND FILTRATION PLANT, LITTLE FALLS, N. J.

Adjustment is made by a rod, which connects with the slide in the tank and passes through the side of the tank to a frame. A milled wheel in a fixed bearing, with a fine adjusting thread, is used to move the orifice plate. A pointer on the rod, over a fixed scale, indicates the length of the opening and facilitates adjustment. The orifice is calibrated for the different divisions of the indicator, and a diagram is used to indicate the corresponding flow.

In the original design provision was made for a series of orifice plates, each plate to contain thirty-two orifices, corresponding to the number of filters. In operation it was the intention to plug as many of these orifices as there were filters out of service, and to have different-sized orifices in each of the series of plates, so as to provide a reasonable range in the rate of application of the sulphate of alumina to the water treated. This design was abandoned, partly on account of the interference with each other of the orifices placed fairly near together, and partly on account of changes in the edges of the orifices due to fine granular deposits which would probably accumulate there.

The device which was built is moderately satisfactory, but has given some trouble, chiefly due to inability to secure at all times a volume of flow corresponding to that indicated by the length of opening of the orifice. Some difficulties of a clogging nature were encountered at first, due principally to splinters from the barrels, which passed through the screens first used in the mixing tanks.

In each of the mixing tanks is an automatic recording gauge which makes a constant record of the depth of solution. For periods of several hours, the differences in the level of the solution in the tank, as read from the gauge, give a satisfactory record of the quantity of solution used. Owing to the size of the tanks, however, this does not give an immediate detection of a change in the rate of flow. This information is now obtained by a float in the orifice tank, which rings a gong as soon as the level of the solution in the small tanks drops 1 in. That is, if the flow is interrupted, in degree equivalent to the full flow for less than one minute, the fact is announced by this gong. Changes in the rate of application of the coagulant solution are secured ordinarily by the indicator connected with the calibrated screw for changing the length of the orifice, but at intervals this is checked by means of a small measuring tank holding about 30 galls., and through which the solution passes on its way to the discharging manifold in the mouth

of the main inlet pipe. With the devices for controlling the coagulant solution as they now stand, it is considered that this branch of the plant is under satisfactory control.

Application of Soda Ash.—At times of heavy floods the alkalinity of the river water becomes very low, and at rare intervals it is necessary to add some alkali in order to ensure complete decomposition of the applied coagulant. Solutions of soda ash are used for this purpose. They are prepared in iron tanks, 6 ft. in diameter and 6 ft. deep. Both hot and cold water are piped to these tanks, in each of which there is a false bottom of perforated brass on which the dry chemical is placed. The tanks are then filled from below, preferably with hot water, the upward current furnishing sufficient agitation to stir the solution. Ordinarily, the solutions as used contain 5% of soda ash. From the tanks, the soda solution is pumped by a triplex pump operated by an electric motor, and enters the raw water in the main inlet pipe about 175 ft. from its entrance into the coagulating basin. Black-iron pipe is used throughout for the soda outfit. The regulation of the flow of the solution is obtained entirely by the speed of the pump.

Cleaning the Basins.—As the bottom of the coagulating basin and of the clear-water basin is below low water in the river, it is necessary, for purposes of cleaning, to pump out the contents of the lower 6 to 10 ft. In the coagulating basin there is a sump, located as shown on the plans, to which the floor slopes slightly. Cast-iron suction pipes lead from this sump to duplicate vertical centrifugal pumps located in the sludge pump well outside the main structure, as shown in Fig. 3. There is also a suction pipe for these pumps extending to suitable sumps in the clear-water basin. To prevent any admission of water from the coagulating basin to the clear-water basin, the valves from these pipes are designed to be interlocked. The pumps are operated by electric motors set on a platform in the well just above high water. The discharge pipes from the sludge pumps are arranged so as to allow a direct discharge of the sediment into the river, or, if desired, into the catch-basin at the eastern end of the plant, from which the overflow reaches the river after leaving behind the bulk of the sediment.

To facilitate the removal of the last portion of the sediment in the coagulating basin, six hose connections with the high-service filtered-water main are distributed around the basin, about 4 ft. from the

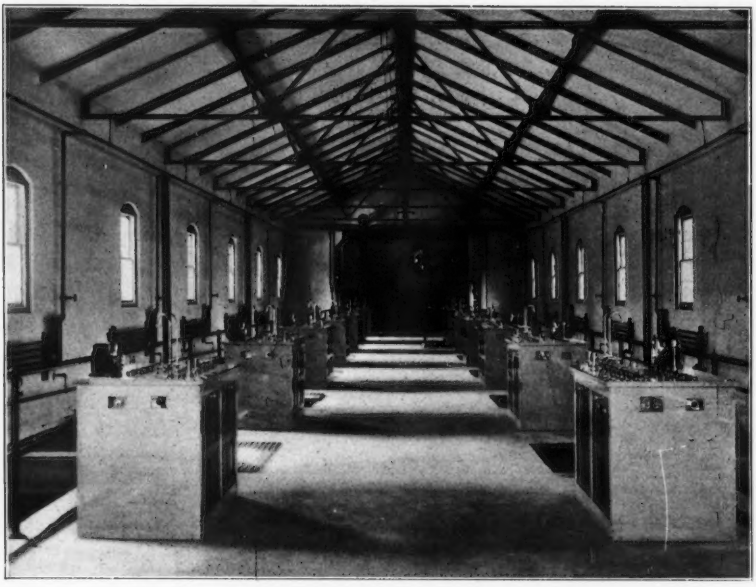


FIG. 1.—OPERATING-ROOM, LITTLE FALLS FILTRATION PLANT.

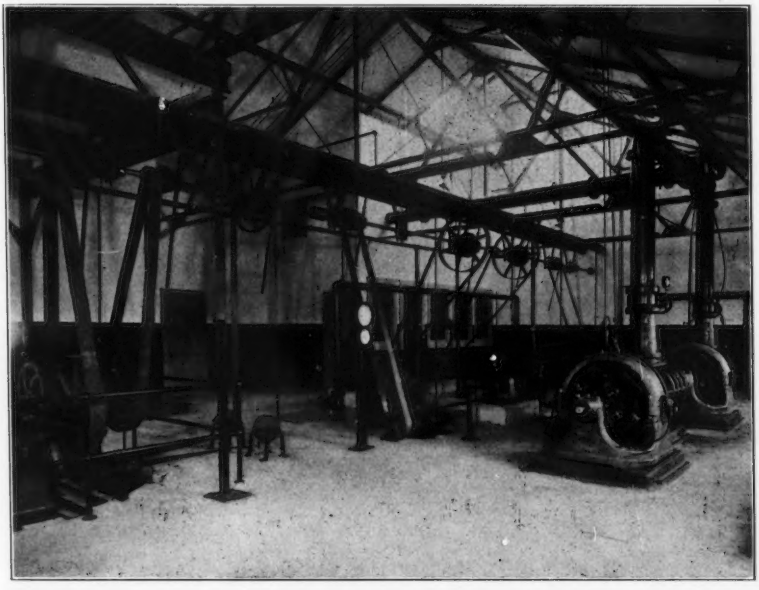


FIG. 2.—MACHINERY-ROOM, LITTLE FALLS FILTRATION PLANT.

bottom. Thus far, the water for flushing purposes has been obtained by opening the gates at the bottom of the stand-pipe, thus admitting raw river water.

Filter-Strainer System.—The strainer system in the floor of the filter comprises a cast-iron header, oval in section, 12 x 6 ins., running lengthwise of the tank in the center, to which are connected $1\frac{3}{4}$-in. cast-iron laterals, set $6\frac{3}{32}$ ins. from center to center. The laterals are cemented into the header, and extend to the sides of the tank, where their ends are closed with cement plugs. Into the header and the laterals are screwed strainers of the Continental type, on $6\frac{1}{4}$-in. centers, there being 1 316 strainers in each filter tank.

The body of these strainers is made of hard cast brass, and the top of cupped brass plate. In each strainer there are 33 holes, $\frac{1}{16}$ in. in diameter in the top and sides. The neck of the strainer is a $\frac{3}{8}$-in. brass tube, which extends into the cast-iron lateral to within $\frac{3}{4}$ in. of the bottom. This extension tube forms a trap when air is applied, and the air passes from the lateral through a perforation in this extension tube, $\frac{3}{32}$ in. in diameter, and located just below the upper wall of the cast-iron lateral.

The connection to the strainer system from below is through the bottom of the tank at the center, where a cast-iron ring is set in the concrete. The central tee of the strainer manifold is bolted to this ring at the top, and at the bottom are fastened the pipe connections which provide an outlet for the filtered water and the inlet for the water and air used in washing. By means of a special double pipe-casting, air is admitted to the strainer system at the top of the central manifold tee, an internal casting in the pipe connection passing up through the ring casting and into the tee. To the lower end of the opening of this internal pipe is connected the air supply line, which passes beneath the floor of the filter to the main air line in the pipe gallery. The outer portion of this special casting forms a water channel, and is connected with the pipe passing under the floor of the filter to the pipe gallery, and is used as an outlet for the filtered water and an inlet for the wash-water.

The space between the lateral pipes is filled with gravel and covered with a cement surface to give a level floor just below the strainers. The construction was such as to facilitate, in case of repairs, ready removal and replacement. The cement surface was coated with two

layers of brick preservative paint, to prevent solution of the cement before it had completely set.

The general arrangement of this strainer system is shown in Plate XXI. At the ordinary rate of filtration the linear velocity of the water in the main header of the manifold, as it leaves the filter tank, is about 2 ft. per second. In the laterals, as the water enters the main header, the velocity is about 1 ft. per second. The exit area of the orifices is equal to 0.37 sq. in. per square foot of filtering surface.

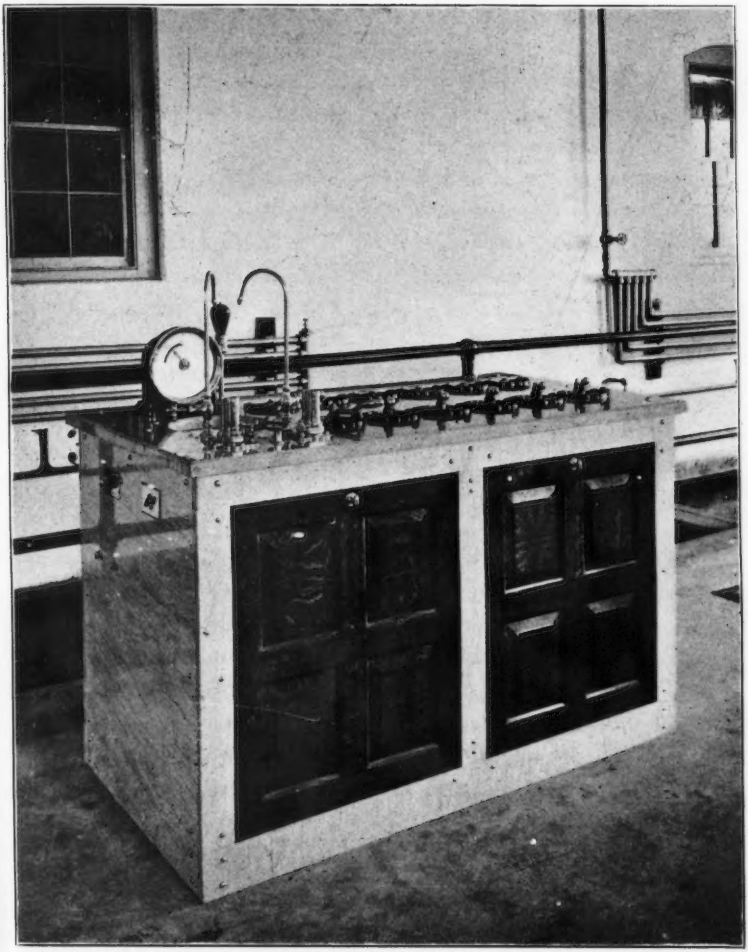
The size of the orifices in the strainer system, $\frac{1}{16}$ in., is larger than in the case of most mechanical filter plants now in service, and it is believed that the resulting freedom from clogging, which, in many instances, is characteristic of fine perforations or fine slots, is a distinct advantage. It is necessary, however, with this type of strainer, always to use gravel to support the sand and prevent it from reaching the orifices. The arrangement of this gravel is described under "Filtering Materials."

The total loss of head, including both friction and velocity head, through the strainer system and outlet pipe, at the normal rate of filtration, 2 galls. per square foot per minute, is about 0.7 ft.

Filtering Materials.—On the floor of the filter there are 2 ins. of broken quartz, above which is a 5-in. layer of finer quartz. The object of these quartz layers, as indicated previously, is to protect the strainer system from the entrance of sand into the orifices and through the outlet pipe into the controllers. The coarser of these two gravel layers was passed through a screen having 4 meshes to the linear inch, and was retained on a screen having 8 meshes. Its effective size is 4.4 mm., and its uniformity coefficient is 1.30. The finer gravel layer was screened between 8 and 12 meshes to the inch. Its effective size is 2.00 mm., and its uniformity coefficient is 1.45.

The success of these gravel layers depends upon the selection of materials of such hydraulic subsiding value that they are not unseated when wash-water is applied at the velocities used, and of a size fine enough to prevent the sand from passing through them.

Regarding the filtering sand, the filter tanks in the north wing are the only ones which have as yet been filled. As this was the only portion of the plant to go into service during the first year, it was decided that it would be advisable to try different sizes of filtering sand and then charge the tanks in the south wing at a later date with the



AN OPERATING TABLE, LITTLE FALLS FILTRATION PLANT.

material which was found to give most satisfactory service under the actual local conditions.

It was specified that the filtering sand, which is 30 ins. in thickness, should have an effective size within the limits of 0.35 to 0.42 mm., with a uniformity coefficient of not more than 1.50. Not more than 1%, by weight, of the sand was allowed to be finer than 0.25 mm., and not more than 0.2% finer than 0.20 mm.

Considerable difficulty was experienced in getting suitable sand. The two sand dealers with whom the contract was placed by the Filtration Company failed to deliver the material, and the commencement of operations was delayed fully one month, during which time the joint efforts of all concerned were devoted to securing suitable sand from any available source. Part of the sand came from near Oyster Bay, Long Island, part from Roslyn, Long Island, and part from Hanover, N. J. The difficulty consisted principally in getting sand from which the fine material was properly eliminated. It was not found feasible, with the screening outfits as built and operated at the several places, to remove the fine material by screening under water. Screening of the sand when absolutely dry seemed to be the only thoroughly successful method of securing the material specified. Sand screening at the several places was watched by representatives of the Water Company, and Allen Hazen, M. Am. Soc. C. E., in the interests of the Water Company, also advised.

The final outcome was that sand containing a considerable excess of fine material was allowed to go into the tanks, and the fine particles were removed by repeated washing of the material in place and scraping of the surface layers. In many cases as much as one-third of the sand as delivered was removed from the filter tanks by scraping. In this way satisfactory results were obtained finally.

As already stated, it was decided to make some differential tests during regular operations, in order to discover the most suitable size of sand for these filters. It was arranged to have two filter tanks charged with relatively coarse material, two others with relatively fine material, and the other twelve tanks in the north wing charged with material fulfilling the original specifications. A summary of the mechanical analyses of the materials in the sixteen filters now in use is given in Table No. 1.

The analyses summarized in Table No. 1 were made during the

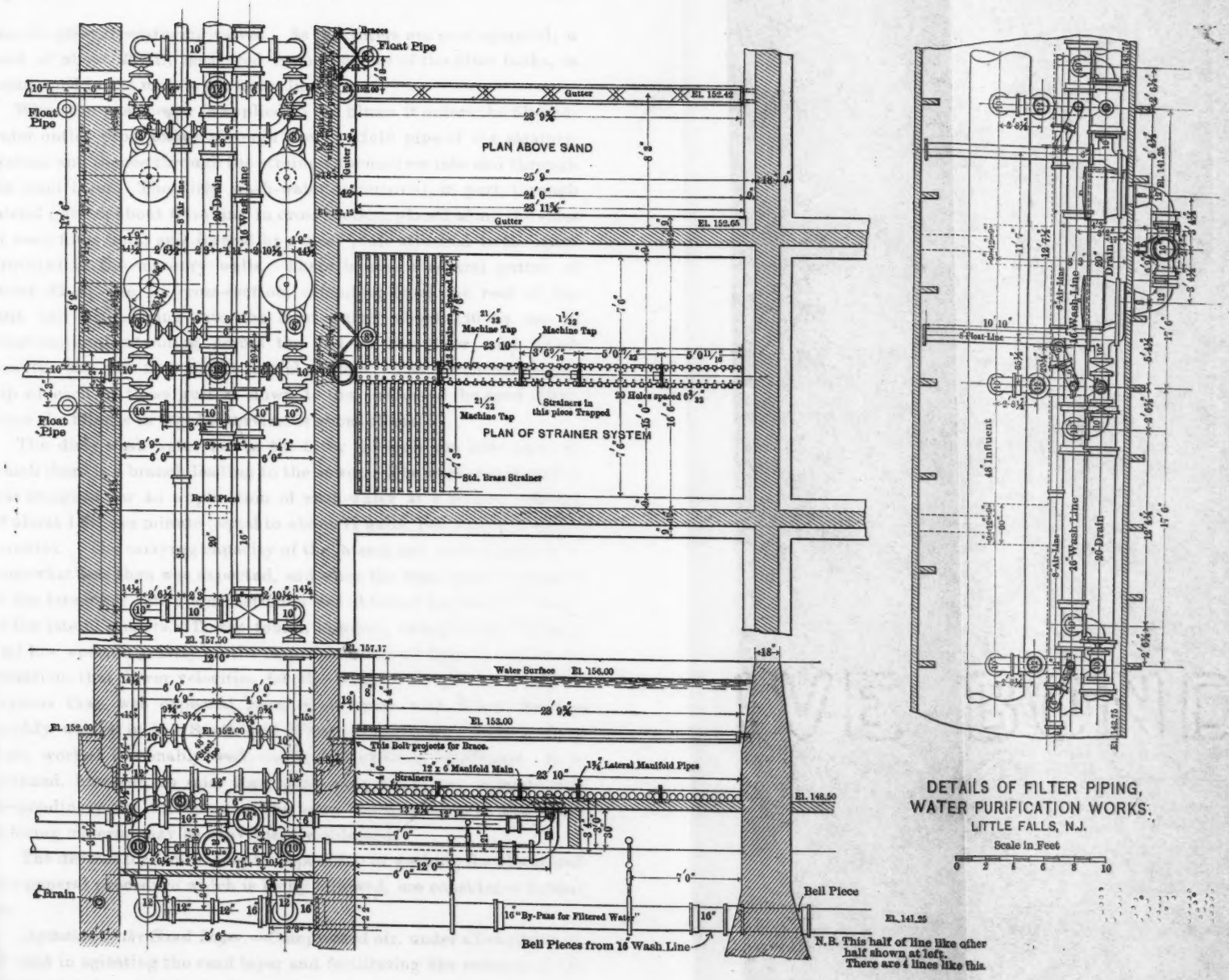
second month of service of the filters. In December, about ¼ in., on an average, was scraped from the surface of the filters. Analyses now being made indicate that the effective size, on an average, has increased about 0.02 mm. The analyses given in Table No. 1 are representative of the conditions under which the results of operation recorded in this paper were obtained.

TABLE No. 1.—SUMMARY OF THE MECHANICAL ANALYSES OF FILTERING SANDS.

Number of filter.	Effective size, in millimeters. (10% finer than.)	Uniformity coefficient.	Percentage finer than:	
			0.25 mm.	0.20 mm.
1	0.44	1.32	0	0
2	0.40	1.50	0	0
3	0.37	1.38	0.2	0
4	0.41	1.44	0	0
5	0.38	1.50	0.4	0.1
6	0.41	1.44	0.1	0
7	0.35	1.50	0.5	0.2
8	0.42	1.43	0.4	0.1
9	0.40	1.42	0.5	0
10	0.41	1.46	0.4	0.2
11	0.37	1.41	0.3	0.1
12	0.46	1.50	0.4	0
13	0.39	1.50	0.2	0.1
14	0.39	1.50	0.2	0.1
15	0.39	1.46	0.2	0.1
16	0.38	1.50	0.1	0.2

The loss of head due to friction in 30 ins. of sand of normal size (effective size 0.41 mm., and uniformity coefficient 1.45) when clean is 1.1, 1.7 and 2.6 ft., respectively, for rates of filtration of 80, 125 and 185 millions of gallons per acre daily. For the coarse sand (effective size 0.46 mm., and uniformity coefficient 1.40) the loss is 1.4 ft. for a rate of 125 000 000 galls. per acre daily.

Wash-Water Appliances.—Wash-water is ordinarily applied to the filters by centrifugal pumps operated by direct-connected motors, and which take their supply from the clear-water basin below the filters. One centrifugal pump and motor is placed in the bottom of each pipe gallery. These pumps have a capacity of 3 000 galls. per minute. The piping is cross-connected, so that either pump may be used for washing one filter at a time in either wing. The wash-water lines are also connected with the force mains leading from the pumping station to the distributing reservoirs in the districts supplied with filtered water. On this connection to the high-pressure



DETAILS OF FILTER PIPING, WATER PURIFICATION WORKS, LITTLE FALLS, N.J.

Scale in Feet

0 2 4 6 8 10

line are pressure-reducing valves. As the filters are now operated, a head of about 25 ft., measured from the floor of the filter tanks, is maintained in the main wash-water line.

When the wash-water is applied to the filters it enters the filtered-water outlet pipe, passes through the manifold pipe of the strainer-system, and thence through the strainers themselves into and through the sand layer. The dirty wash-water is removed, in part, through lateral gutters about 60 sq. ins. in cross-section, placed along the sides of each filter tank, and formed by a steel plate attached to the ledge provided in the masonry walls. There is also a central gutter, of about 85 sq. ins. in cross-section, extending from the rear of the tank and discharging into the front gutter about 140 sq. ins. in cross-section, extending across the end of the filter, and which receives also the flow of the lateral gutters. The distance from the top of each of these gutters down to the surface of the sand layer, when the filter is in regular service, is about 12 ins.

The dirty wash-water leaves the filter through the inlet pipe, to which there is a branch leading to the sewer. The wash-water system was designed for an application of wash-water at a vertical velocity of about 1 ft. per minute (equal to about 7½ galls. per square foot per minute). The carrying capacity of the lateral and central gutters is somewhat less than was expected, and when the wash-water is applied at the foregoing rate a weir action is not obtained for the full length of the lateral gutters. It was found, however, owing to the fineness and low specific gravity of the materials removed from the water by filtration, that lower velocities for the wash-water are more advantageous than was expected, from experiences with filters treating muddy waters in the South and West. Accordingly, these gutters have worked reasonably well, under the existing conditions. It is planned, however, to raise them some 3 or 4 ins. and increase correspondingly the thickness of the sand layer, as soon as additional filtering material may be conveniently obtained.

The devices for facilitating the operation of washing the filters, and the general procedure which is being followed, are considered further on.

Agitation of the Sand Layer.—Compressed air, under a low pressure, is used in agitating the sand layer and facilitating the removal of the accumulated materials during washing, in place of the mechanical stirring devices with rake arms, such as have been used in the majority

of filter plants now in service. In the machinery-room there are two No. 3, Root's rotary blowers, of standard make, direct-connected with electric motors. Each has a guaranteed capacity of 1 500 cu. ft. of free air per minute, under a pressure of 5 lbs. From the main air line, running lengthwise of each pipe gallery, there is a branch to each filter, passing beneath the filter floor and entering the special casting below the center of the floor of the filter. The air is delivered at the top of this casting, thence it passes through the manifold piping system to the trapped strainers, next through a small orifice in the strainer-tube extension near the top of each lateral pipe, and thence through the several strainers. The rate of application of air used ordinarily is about 1 000 cu. ft. per minute, under a pressure of 3 lbs. The distribution of the air through all the strainers is uniform to a satisfactory degree, and it agitates the sand bed efficiently, causing the grains to be rubbed together, and with facility freed from the films of organic and other matters which surround the individual grains.

In no instance is agitation with air used at the same time that the wash-water is applied to the filters. The application of air forms the first step in the process of cleaning, and then, after the wash-water has been applied to secure fairly thorough cleaning, the air has been again applied for about one minute to effect further cleansing. During the application of air the water stands in the filters about 4 ins. above the top of the sand surface, or 8 ins. below the top of the overflow gutters. The applied air raises the sand layer about 3 ins., but it does not cause the entire mass to become floated as in the process of washing. Water is always used after the last application of air, and thus the sand layers are freed from any entrained air. The application of air in the manner described does not effect any appreciable grading of the sand grains.

Filter Piping and Connections.—Plate XXI shows a plan and section indicating the size and general arrangement of the piping, all of which is placed within the pipe gallery, together with the connections to the filters. The sizes of the leading pipes are as follows:

Main raw-water supply	48 ins.
" wash-water supply	16 "
" air supply	8 "
" drain	20 "
Individual filtered-water outlet	10 "
" raw-water inlet	12 "
" air line	6 "

The main inlet pipe is of riveted steel, and is carried on hangers attached to the Ransome beams supporting the operating floor. All other pipe is of cast iron. Flange valves were used throughout, but hub and spigot joints were put in wherever possible, both on account of cost and the greater ease of erection and connection to the masonry structures. It was the aim, also, to distribute the flange and hub connections so that in the event of a break the broken piece would be most easily removed.

Effluent Controller.—Each filter is provided with an automatic controller, of the well-known Weston type, consisting essentially of a moving orifice operated by a float in an open compartment. The water enters the controller through butterfly valves, which are operated by the float. The action of these controllers is to maintain a uniform rate of discharge, independent of the head on the outlet pipe. Accordingly, the filters are always operated during filtration with the valve on the outlet pipe wide open, and the flow is controlled automatically by this device.

Orifice discs of three different sizes are provided with each controller, giving yields of about 1 000 000, 1 250 000 and 1 500 000 galls. per filter per 24 hours, respectively. There are also a few special discs to give a daily yield of 650 000 galls.

The head lost in these controllers, as measured from the water level in the outlet stand-pipe (when the float in the controller is seated) to the top of the pipe gallery floor, is about 2.5, 3.0, or 4 0 ft., when the yields of the filters are 650 000, 1 000 000 or 1 500 000 galls. daily, respectively.

These controllers are placed in the bottom of the filter gallery, and discharge the filtered water through an outlet pipe directly into the clear-water basin below. By means of a galvanized-iron funnel and cross-connection pipe, the water from any filter may be discharged into the opposite compartment of the clear-water basin when desired.

Hydraulic Valves.—All the valves on the filter piping are of Rensselaer make, are generally light-weight, double-disc gate-valves, and are operated by hydraulic cylinders. The valves on the wash-water line are all heavy weight. The water to operate these cylinders is furnished by a separate, high-service line, the connections from which are controlled by special four-way cocks. They are operated by levers, with indicators showing the position of the valves, conveniently

located on the operating table in front of each filter on the platform above the pipe gallery.

Loss-of-Head Gauges.—On each operating table there is a loss-of-head gauge, the dial of which is operated by a float in the water above the sand layer in the filter, and the pointer of which is operated by a float in a small stand-pipe connected to the outlet pipe through which the filtered water passes to the controller. These gauges, which were designed and made by the Filtration Company, are somewhat novel, in that there is an automatic adjustment of the zero point of the gauge to different water levels in the filters. By means of this adjustable dial the reading of the pointer gives the frictional resistance, or loss of head, in the filter at any time. Electrical connection is made when the loss of head reaches the maximum, so that a bell is rung and an electric light is turned on, thus warning the operator that it is time to wash the filter.

Available Head.—The gross head available, measured from the top of the filter tanks to the maximum water level in the clear-water basin, is 14 ft. Ordinarily, the water level on the filters is kept about 1 ft. below the top of the filter walls, giving an available head of 13 ft.

In a filter containing normal sand, and operated at the regular rate (1 000 000 galls. per 24 hours), the loss of head, directly after washing, averages 2.3 ft. Adding this to the head lost by the controller, there is left a net effective head of 7.7 ft. for overcoming the friction caused by the accumulations of sediment, etc., in the sand layer. With a filter containing coarse sand (0.46 mm. effective size), and operated at the regular rate, this effective head is 8.0 ft. With a filter containing normal sand, and operated at a rate of 1 500 000 galls. per 24 hours, the net effective head is 5 ft.

Arrangement of Devices for Operating the Plant.—Unusual attention was given to making the operation of this plant as automatic as practicable, with provisions for indicating to the man in charge the status of the various operations at all times.

Mention has already been made of the devices in connection with the preparation and regulation of the flow of the chemical solutions, the automatic filter controllers, hydraulic cylinders for the operation of the valves, and the loss-of-head gauges. In addition to these the detailed arrangements include gauges for indicating the water levels in the coagulating basin and clear-water basin, and devices for sampling

the water as it passes through the plant. In the general office are two glass cylinders through which pass constant streams of raw and filtered water.

Each filter is provided with an arrangement by which a sample of filtered water from it may be collected readily at any time. In the pipe gallery opposite the outlet pipe of each filter is a small Pelton water-wheel operated from the high-service line. This wheel operates two ¼-in. centrifugal pumps, the suction of one of which is in the filter outlet pipe, and the other in the filter inlet pipe. The discharge of each is piped to the operating table, where there are cocks on the pipes to control the flow into a sink. These devices enable the operator to collect at each filter samples of the raw water on its way to the filter, the filtered water as it leaves the filter, or the dirty wash-water after it leaves the filter during the washing process. There are, also, at each operating table, sight tubes, the intended purpose of which is to show the character of the filtered water, the raw water, or the dirty wash-water, as the case may be. These devices for inspecting the filtered water and collecting samples of it have proved very helpful. The sight-tubes, however, as they now stand, have not proved very satisfactory, owing to the illumination being furnished by lamps which are not suitable. The intense brown appearance of the dirty wash-water, due to the organic matter contained therein, makes it improbable that the sight-tubes will ever be of much assistance in this plant in determining when the application of wash-water should cease. This can be found much better by an inspection of the water in the filter tank itself, which is illuminated by an electric light favorably situated.

Plates XIX and XX show the general arrangement of the filter-house and the marble operating tables placed opposite each filter.

Description and Results of Operation.

In brief terms, the general procedure of operating a mechanical filter plant of this character may be said to consist of the preparation of solutions of coagulating chemical, the application of the same to the river water in quantities adapted to its character, the cleaning of the filters from time to time when the clogging materials in the sand layers exhaust the available head, and the adjustment of the number of filters in service to yield the quantity of filtered water corresponding to the demands made upon the clear-water basin by the main pumping station.

With a plant equipped with such automatic devices as are provided at these works the operation of the filters themselves is a simple matter, and can be entrusted to ordinary intelligent laborers, subject to the oversight of a foreman. The preparation and application of solutions of coagulant require somewhat more attention, and, to be done effectively, and at the same time economically, there is required the attention of an intelligent and watchful superintendent capable of taking advantage of a certain amount of analytical evidence showing from time to time the character of the water which he has to treat. There are, of course, some other matters occasionally requiring attention, such as the cleaning of the coagulating basin, the packing of valves, and other work incidental to such a system of piping and mechanical appliances.

These filtration works, as already stated, have been in continuous service since September 4th, 1902. During the first year of service this plant is being operated under the general oversight of the writer, and during the first six months it has been under the immediate charge of Mr. George A. Johnson.

The object of conducting a series of careful investigations of the plant during its initial year of service is to obtain information whereby the plant can be operated to best advantage in the treatment of the local water as it passes through its various seasonal changes, and especially to ascertain the most judicious manner of coagulating the water and of washing the filters, and to prepare schedules whereby the regular attendants may operate the plant properly, at a later date.

As already stated, the filter tanks in the south wing have not yet been charged with sand, and among the special studies undertaken is that of the determination of the size of sand best adapted to local conditions. These and other matters led to establishing at the outset a schedule which involved the determination of data upon several points of importance.

Differential Tests.—Twelve of the sixteen filters in the north wing have been used regularly for obtaining data for differential or comparative purposes. They consist of six pairs, in duplicate. One pair contains the normal sand as originally specified, another coarse sand, another fine sand, another normal sand operated at a high rate, and another normal sand operated at a low rate. The final pair contains normal sand in which no air is used in cleaning the sand layers. Wash-

water and air are applied in the same manner to the five pairs of filters first mentioned. Unless otherwise stated, the rate of filtration is normal, 125 000 000 galls. per acre daily, or about 2 galls. per square foot per minute. The remaining filters in the north wing, when in service, are used for studying the best rate of application of wash-water and of air, and of other allied matters which can be taken up as individual studies.

The essential details of the twelve filters used for differential purposes are indicated in Table No. 2.

TABLE NO. 2.—SUMMARY OF THE ESSENTIAL DETAILS OF FILTERS.

Filter number.	Sand Layer.			Air used in washing.	Rate of Filtration.	
	Grade.	Effective size. Millimeters.	Uniformity coefficient.		Millions of gallons per acre daily.	Approximate gallons per square foot per minute.
1.....	Coarse.	0.44	1.32	Yes.	125	2
12.....	Coarse.	0.46	1.50	Yes.	125	2
3.....	Fine.	0.37	1.38	Yes.	125	2
7.....	Fine.	0.35	1.51	Yes.	125	2
2.....	Normal.	0.40	1.50	Yes.	125	2
8.....	Normal.	0.42	1.43	Yes.	125	2
13.....	Normal.	0.39	1.50	No.	125	2
16.....	Normal.	0.38	1.50	No.	125	2
9.....	Normal.	0.40	1.42	Yes.	80	1.25
10.....	Normal.	0.41	1.46	Yes.	80	1.25
4.....	Normal.	0.41	1.44	Yes.	185	3
6.....	Normal.	0.41	1.44	Yes.	185	3

Force Employed.—Owing to the amount of work involved by the special tests, together with all other special studies indicated herein, the force employed in the operation of these works, up to the present time, has been considerably in excess of that which will suffice later. It is also to be borne in mind that at the outset the attendants employed for the operation of this plant were entirely unfamiliar with the operation of mechanical filters, and that there has been necessary a period of instruction during which it was important not to require of the men more detailed observations than they could readily make. Thus far, Mr. Johnson has been assisted by nine men, three of whom were technically trained. Of the latter, one devoted himself exclusively to engineering matters and the compilation of results, one to analytical work, and the third to general work both in the laboratory and in operating the plant. There is one filter attendant on each

watch of twelve hours, and one man in the machinery-room. There is also one mechanic on duty during the day, and one boy, as general helper in the laboratory and as janitor.

When the plant is operating at full capacity in the future, it is expected that there will be two trained men, say, a superintendent and an assistant superintendent, both of whom will be familiar with ordinary analytical matters, and two filter attendants and one attendant in the machinery-room, on each watch. Besides these there will be a janitor or laboratory helper. At times there will be required some service by a mechanic, in connection with the machinery, but it is expected that this can be attended to by the mechanics employed at the pumping station nearby. Assuming that there will be required the service of a mechanic equal to continuous labor of one man per day, the total force employed, with 12-hour shifts, would be ten men, including the man in charge and his principal assistant.

Observations and Analyses Made.—A close watch has been kept upon all principal features connected with the operation of these works. Hourly readings of the levels of the water in the coagulating basin and clear-water basin, and in the coagulant solution tanks are taken and recorded, as well as of the loss of head as indicated by the gauges on each filter in service. Careful records are also made of all observations connected with the washing of filters, enabling a continuous and complete record to be maintained for each filter, as to the periods between washings, the quantity of water filtered and the amount of wash-water and air applied.

Regarding analytical work, samples of the river water and the effluents of the coagulating basin and the clear-water basin are collected three times a day, to be examined for numbers of bacteria, amount of turbidity, color, amorphous matter and alkalinity. The water before and after filtration is also examined for color and turbidity at 2-hour intervals. At least once each day, a sample from the effluent of each individual filter in service is examined bacterially. From time to time samples of the filtered water from each filter in turn have been collected at frequent intervals, to show the uniformity in composition of the filtered water. At frequent intervals most careful tests have also been made regarding the presence of coagulant in the filtered water. Once a week, as a rule, chemical analyses of the raw and filtered water have been made. In addition to

this, many special observations have been made, in order to throw light upon such matters as the best manner of washing the filters, judged by the rate at which the clogged materials were removed from the sand layer, as shown by the character of the dirty wash-water. Frequent analyses of the sand layers have also been made, not only for their contents as to bacteria and suspended matters, but also to show their uniformity in size as indicated by mechanical analyses.

Up to February 1st, the amount of analytical work performed is indicated by Table No. 3.

TABLE NO. 3.—SUMMARY OF ANALYTICAL WORK.

Complete chemical analyses	30
Partial analyses, for alkalinity, alumina, color and turbidity	5 120
Other special analyses, including specific gravity of coagulant solution	340
Complete microscopical examinations	16
Partial examinations for amorphous matter	148
Examination for numbers of bacteria	4 260
Mechanical analyses of filtering material	545

Record of Results.—A record of the principal results obtained is given in Tables Nos. 4 and 5.

Table No. 4 is a summary of the leading results by days, including the amount of coagulant applied, the percentage of wash-water, and the alkalinity, turbidity, color, amorphous matter and bacteria in the river water, the effluent of the coagulating basin and the effluent of the filters.

Table No. 5 shows the results of the chemical analyses of the raw and filtered water.

The number of microscopical organisms in the river water has ranged from 20 to 200 per cubic centimeter.

Coagulant.—Sulphate of alumina is the coagulant which has been used regularly thus far. Arrangements have been made for the application of copperas and lime, with the view to seeing if such treatment is applicable for purposes of coagulation under the existing local conditions, and, if so, to ascertain the cost, as compared with sulphate of alumina.

TABLE No. 4—(*Continued*).

Daily Summary of Leading Average Results of Operation.

Day, Oct., 1902.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.									Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.				Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.		River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	9.37	4.1	1.76	18	9	12	8	0	50	30	7		3 500	620	11 000	350	60
2	8.36	4.2	1.67	16	7	10	7	0	48	31	6		2 000	600	2 800	170	28
3	8.31	4.1	1.22	19	9	9	7	0	48	19	12		1 100	600	2 100	250	75
4	6.65	5.4	1.19	19	12	9	5	2	50	33	27		1 050	400	1 000	290	275
5	6.10	5.9	1.49	19	11	8	6	2	50	32	19		1 200	800	2 700	325	65
6	6.97	4.9	1.55	20	8	8	7	0	50	29	8		1 500	300	2 700	325	28
7	7.02	4.3	1.40	19	10	8	6	0	51	27	7		800	200	1 200	650	80
8	6.57	5.3	1.36	21	10	8	6	0	52	28	8		800	290	750	700	24
9	5.84	5.9	1.36	20	11	7	5	1	51	27	9		1 500	600	2 300	425	160
10	6.17	5.4	1.44	22	12	6	5	1	58	35	12		1 500	500	2 300	1 100	200
11	6.68	5.5	2.01	22	13	5	4	1	59	36	9		500	200	6 800	950	220
12	5.76	6.0	1.65	18	11	4	3	0	51	30	4		.....	.....	14 000	1 300	300
13	8.03	4.3	1.46	17	9	5	4	1	56	37	5		300	100	3 700	1 000	160
14	6.64	5.9	1.31	23	12	5	4	1	55	37	10		1 000	300	6 900	450	170
15	7.51	4.5	1.79	24	10	5	5	1	57	27	6		1 200	500	600	160	19
16	8.13	4.3	1.93	23	10	5	4	1	57	28	3		1 500	500	325	200	11
17	8.85	3.8	2.17	23	7	4	3	1	54	33	3		1 000	400	500	130	12
18	8.23	4.1	1.95	27	7	3	3	1	51	29	3		800	200	600	100	16
19	8.81	4.8	1.65	26	11	3	3	2	53	30	2		700	400	300	120	15
20	6.20	6.0	1.63	26	14	3	3	2	52	33	5		1 000	200	275	120	25
21	8.50	4.5	1.61	29	12	3	3	2	53	34	6		1 500	400	300	140	50
22	7.02	5.5	1.65	26	13	4	5	1	53	36	6		1 200	400	700	350	48
23	7.19	5.1	1.66	27	14	5	3	1	53	32	6		1 000	400	1 000	450	36
24	7.40	5.4	1.65	30	16	3	4	1	54	38	4		1 200	400	1 000	600	60
25	9.85	3.6	1.73	32	18	4	4	1	53	35	3		1 000	300	3 100	475	80
26	8.83	3.8	1.52	36	20	4	4	2	49	29	3		1 200	350	1 600	900	150
27	8.61	3.8	1.45	32	20	3	3	2	49	26	2		800	290	3 900	1 000	100
28	8.36	4.4	1.54	28	15	7	5	2	42	38	2		800	300	18 300	3 200	110
29	11.39	3.3	1.45	18	8	7	6	1	51	34	4		900	300	13 600	1 100	100
30	10.27	3.8	1.61	18	9	5	5	1	51	29	4		700	280	7 200	1 500	95
31	8.12	4.5	1.52	17	7	7	7	1	50	22	4		600	180	3 500	1 400	34
Averages	7.79	4.8	1.59	23	12	6	5	1	52	31	7		1 100	380	3 800	650	90

TABLE No. 4.

Daily Summary of Leading Average Results of Operation.

Day, Sept., 1902.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.									Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.				Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River. water.	Subs. water.	Filt. water.		River water.	Subs. water.	River water.	Subs. water.	Filt. water.
4	6.61	5.3	1.31	51	41	7	..	3	28	..	6		.....	.....	1 100	.....	200
5	10.12	3.8	0.64	50	44	8	..	2	30	..	8		.....	.....	1 500	.....	150
6	10.55	3.5	0.39	51	44	8	..	3	32	..	10		.....	.....	2 000	.....	150
7	11.49	2.9	0.32	48	46	8	5	5	29	15	15		.....	.....	2 000	1 300	200
8	14.52	2.4	0.35	48	46	9	4	5	29	21	15		.....	.....	400	.....	210
9	10.13	3.3	0.29	56	46	9	4	5	29	20	16		.....	.....	4 000	1 100	400
10	8.23	4.2	0.75	54	48	11	5	2	28	10	7		.....	.....	1 000	500	350
11	7.65	4.4	0.68	46	40	10	5	2	28	10	8		.....	.....	1 400	425	170
12	8.47	4 0	0.52	44	39	9	5	2	25	10	8		.....	.....	1 600	500	170
13	8.90	3.9	0.62	39	34	8	4	2	25	18	15		.....	.....	1 900	400	170
14	8.68	4.2	0.64	39	35	8	4	2	24	..	10		.....	.....	.....	.....	....
15	8.00	4.3	0.67	40	35	9	4	2	23	15	10		.....	.....	1 800	500	160
16	7.98	4.2	0.65	41	36	9	5	2	23	16	7		.....	.....	850	475	110
17	8.01	3.9	0.72	45	40	7	3	2	28	15	8		.....	.....	700	350	170
18	8.12	4.1	0.74	44	39	9	5	2	28	18	8		.....	.....	1 500	1 000	150
19	9.00	3.7	0.78	43	38	9	5	2	28	28	4		.....	.....	2 500	400	210
20	8.10	4.0	0.70	44	38	8	4	2	31	20	7		.....	.....	1 700	250	150
21	7.67	4.3	0.83	45	39	8	6	2	36	22	9		.....	.....	1 500	375	120
22	8.52	3.9	0.89	47	40	11	..	2	45	24	6		.....	.....	1 000	750	325
23	7.03	4.9	0.79	47	41	7	4	2	22	13	6		.....	.....	400	250	80
24	7.71	4.5	0.83	47	42	7	4	2	26	19	6		.....	.....	400	110	30
25	7.23	4.9	0.81	49	42	8	3	2	25	18	7		.....	.....	700	65	60
26	6.82	5.2	0.74	48	39	11	7	3	24	23	11		.....	.....	.....	.....	....
27	6.35	6.8	0.75	28	23	20	14	5	38	25	25		.....	.....	.....	.....	....
28	7.42	5.0	1.19	17	12	15	10	4	35	32	24		.....	.....	3 600	2 000	300
29	7.89	4.6	1.24	16	9	18	11	3	54	32	21		2 800	.....	12 000	8 000	400
30	7.22	5.1	1.31	19	9	15	8	3	52	34	22		2 400	.....	80 000	59 000	220
Averages	8.46	4.3	0.74	42	36	10	6	3	31	20	11		.....	.....	5 400	3 900	190

The quantity of amorphous matter is expressed in standard units, according to Whipple's method. Standard nutrient gelatine, reaction 1½% acid, is used in determining the numbers of bacteria, the period of cultivation being 48 hours, at 20° Cent.

TABLE No. 4—(*Continued*).

Daily Summary of Leading Average Results of Operation.

Day, Dec., 1902.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.								Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	13.18	3.2	1.70	32	19	4	3	1	47	33	5	120	50	5 500	2 300	75
2	11.60	3.5	1 59	32	18	3	3	1	43	32	6	130	70	4 800	1 900	40
3	14.91	2.9	1.72	30	17	5	3	2	46	29	4	110	40	8 900	2 400	50
4	10.84	3.8	1.61	28	16	4	1	1	46	29	5	110	40	9 200	3 000	40
5	12.11	3.5	1.82	26	13	5	3	1	48	31	6	130	50	13 000	3 300	35
6	11.52	3.7	1.48	25	13	5	3	1	53	37	6	250	70	10 100	2 500	75
7	10.22	4.2	1.75	25	12	4	3	0	45	30	6	350	90	9 800	1 700	55
8	10.89	3.8	1.73	25	13	4	2	1	48	23	6	300	150	9 200	3 200	140
9	9.38	4.5	1.53	25	13	3	2	1	47	27	4	280	100	7 200	3 300	375
10	10.94	3.8	1.73	27	13	3	2	0	51	21	6	240	110	5 300	2 100	100
11	8.54	4.5	1.70	28	14	3	1	1	47	20	6	160	80	3 400	1 100	33
12	12.36	3.2	1.75	28	16	3	2	0	37	18	5	150	70	2 800	1 100	30
13	8.78	4.5	2.01	28	17	2	1	1	41	29	6	130	70	2 800	600	29
14	9.80	4.1	1.68	29	17	2	1	1	35	18	6	190	100	2 100	500	25
15	11.09	3.6	1.72	28	17	2	1	1	34	18	5	250	130	3 700	400	25
16	7.75	5.2	1.83	23	14	6	4	1	42	18	5	230	130	6 600	1 100	32
17	5.91	7.4	1.85	10	7	10	5	1	49	19	4	1 700	500	10 100	500	60
18	9.09	4.5	2.00	10	6	14	8	2	44	24	5	800	400	9 200	2 200	60
19	8.29	4.7	1.79	10	7	13	8	2	51	25	6	600	300	8 900	4 800	70
20	8.77	4.4	1.76	11	7	16	11	1	42	21	4	300	160	9 900	2 500	45
21	9.27	4.5	1.93	12	7	11	7	0	41	23	4	1 000	500	4 400	1 700	18
22	8.16	4.9	1.82	9	6	19	15	1	48	25	4	1 200	450	5 800	1 700	27
23	8.23	4.9	1.84	8	5	19	8	1	43	21	3	1 100	550	3 200	1 600	25
24	10.38	4.1	1.72	10	6	12	6	1	38	21	5	900	500	6 800	2 300	39
25	10.24	3.9	1.73	11	8	7	5	0	49	22	4	800	390	4 000	1 400	35
26	10.51	3.8	1.77	12	8	9	7	1	45	20	5	600	320	4 200	1 200	36
27	9.98	3.9	1.37	14	12	7	4	0	45	20	4	500	280	3 600	1 700	28
28	9.55	4.0	1.49	15	10	9	4	0	41	23	4	410	250	3 600	1 000	14
29	9.13	4.1	1.46	17	9	9	4	1	43	25	4	310	180	6 700	850	11
30	9.56	4.0	1.49	18	8	4	3	0	32	22	4	250	130	2 300	800	7
31	9.43	4.1	1.35	18	9	3	2	1	28	18	5	200	100	1 700	800	6
Averages	10.02	4.2	1.70	23	12	7	4	1	44	24	5	450	210	5 800	1 800	50

TABLE No. 4—(*Continued.*)

Daily Summary of Leading Average Results of Operation.

Day, Nov., 1902.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.								Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	7.41	5.0	1.05	19	14	4	4	3	51	45	28	800	290	1 700	1 300	210
2	3.93	10.8	1.63	20	13	6	6	3	47	34	14	700	220	1 300	500	70
3	7.93	5.4	1.55	21	11	3	3	2	49	24	4	400	140	1 200	225	19
4	7.62	5.3	1.57	22	11	4	3	2	50	33	5	300	90	1 300	350	24
5	6.99	6.0	1.70	24	11	5	4	2	51	39	6	210	60	1 200	400	48
6	7.47	5.4	1.76	25	13	5	4	1	52	28	6	400	95	1 800	550	12
7	7.44	5.7	1.81	26	16	6	4	1	49	28	6	500	100	2 400	550	11
8	8.13	4.8	1.44	26	18	6	4	2	47	16	7	280	80	3 100	550	33
9	7.81	5.5	1.94	27	15	5	3	2	44	25	5	340	90	2 800	550	60
10	4.54	10.9	1.75	27	15	5	3	1	47	38	5	120	35	1 900	375	45
11	9.12	4.8	1.80	29	22	5	3	2	47	33	20	310	75	3 100	425	15
12	11.97	3.4	1.79	29	18	5	3	1	49	33	4	190	50	1 400	475	16
13	10.12	4.0	1.71	29	18	5	3	3	45	24	5	150	40	1 800	500	22
14	12.29	3.3	1.60	32	21	5	4	2	46	30	5	110	40	2 600	800	27
15	10.09	3.8	1.65	33	20	5	3	2	49	31	4	400	95	1,700	1 000	25
16	10.75	4.0	1.64	32	21	6	5	3	45	29	4	300	85	2 900	650	25
17	11.81	3.7	1.47	32	22	7	5	2	41	28	4	350	100	1 900	600	23
18	10.84	3.7	1.56	35	22	6	4	2	39	26	5	200	55	1 500	900	22
19	10.68	4.3	1.77	35	22	5	5	3	38	27	4	170	40	1 300	450	11
20	10.64	3.8	1.64	36	24	5	5	3	39	28	8	150	40	1 400	475	19
21	10.88	3.8	1.75	36	24	5	5	2	42	23	4	230	50	2 300	500	7
22	11.70	3.5	1.78	35	24	6	5	1	41	24	3	200	50	4 200	850	37
23	11.50	3.5	1.58	36	25	3	3	2	43	26	4	150	60	7 000	1 800	42
24	11.14	3.8	1.60	35	24	4	4	1	44	27	3	180	40	5 000	2 100	170
25	10.14	3.9	1.35	35	25	3	3	1	44	27	5	250	50	8 000	5 000	90
26	8.56	4.8	1.41	35	26	3	3	1	38	30	5	280	70	5 200	2 200	325
27	8.09	5.4	1.31	34	23	3	3	1	48	24	6	300	80	6 700	2 900	180
28	11.46	3.7	1.57	34	22	4	4	2	49	24	5	180	40	9 800	3 600	100
29	10.29	4.1	1.89	33	19	5	5	1	47	36	6	120	50	11 600	2 300	100
30	12.79	3.4	1.73	32	17	5	5	2	45	32	7	100	30	5 400	1 500	20
Averages	9.46	4.8	1.63	30	19	5	4	2	45	28	7	280	80	3 500	1 100	60

TABLE No. 4—(*Concluded*).

Daily Summary of Leading Average Results of Operation.

Day, Jan., 1903.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.								Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	10.82	3.6	1.05	20	11	2	2	0	39	20	4	220	100	1 700	750	12
2	13.09	3.1	0.93	21	13	3	2	0	28	18	3	180	75	1 500	1 200	21
3	10.03	4.0	1.12	19	12	4	3	0	25	18	4	100	50	3 200	1 600	12
4	10.33	3.8	1.03	16	9	3	2	0	25	17	6	90	40	4 400	2 600	17
5	12.81	3.1	0.90	16	9	4	3	1	28	18	5	100	50	4 400	2 600	80
6	11.62	3.3	0.68	16	10	5	3	0	37	21	5	80	40	3 700	1 800	140
7	13.41	2.9	0.57	17	11	4	3	0	35	24	10	140	110	2 400	2 000	400
8	10.54	3.6	0.68	17	12	3	2	0	32	26	5	130	70	1 600	1 200	275
9	13.11	3.0	0.64	18	13	3	1	1	32	19	6	120	80	1 200	850	65
10	11.79	3.2	0.67	19	14	2	1	0	29	22	6	140	90	2 200	210	55
11	12.40	3.0	0.66	20	16	1	2	0	29	19	6	160	70	650	190	110
12	13.52	2.9	0.66	21	16	5	3	1	28	20	4	190	110	2 100	900	150
13	9.71	4.2	6.76	24	18	4	3	1	27	22	6	150	190	1 600	500	160
14	12.79	3.0	0.61	24	20	4	2	0	28	18	6	120	70	1 400	1 200	190
15	12.81	2.9	0.69	24	19	4	3	0	28	20	6	110	75	1 500	1 300	70
16	12.75	3.0	0.80	24	18	3	2	0	26	19	5	130	80	1 800	650	80
17	15.90	2.3	0.73	25	20	4	2	0	23	17	5	150	90	2 300	1 400	100
18	18.08	2.2	0.68	25	20	3	3	0	22	16	5	150	75	4 200	1 000	130
19	16.55	2.2	0.65	27	22	3	3	0	22	17	4	140	80	4 000	2 600	190
20	15.38	2.4	0.56	28	24	3	2	0	23	17	5	120	60	5 200	1 200	300
21	12.79	3.0	0.71	22	19	20	17	0	31	24	6	120	70	6 000	2 300	225
22	10.54	3.7	1.03	16	9	23	11	0	35	25	6	700	400	5 600	1 700	120
23	12.64	3.0	0.92	15	8	14	9	0	36	25	5	500	300	4 300	950	80
24	11.80	2.9	0.94	16	9	12	8	0	36	23	5	400	250	8 900	3 000	150
25	14.93	2.3	0.98	17	10	13	2	0	49	32	5	300	160	11 200	3 200	140
26	11.26	3.3	1.06	18	10	12	10	0	46	27	5	210	100	9 400	3 200	85
27	14.02	2.5	1.27	20	11	11	7	0	42	26	5	180	90	6 700	2 900	40
28	12.58	2.9	1.35	21	11	10	6	0	43	26	5	300	180	4 700	1 600	45
29	11.02	3.0	1.24	19	10	9	5	0	35	20	5	280	150	5 800	1 100	22
30	10.80	3.1	1.08	18	11	8	5	0	30	17	4	250	130	4 500	1 800	34
31	12.87	2.3	0.80	16	10	9	7	0	30	20	5	280	150	5 200	3 900	65
Averages	12.67	3.0	0.84	20	14	6	5	0	31	21	5	200	115	4 000	1 700	110

TABLE No. 5.—Results of Chemical Analyses of River Water and Filtered Water.

(Parts per Million.)

Collected. Date, 1902.	Hour	Source. R = River water. F = Filtered water.	Temperature, in degrees Centigrade.	Silica turbidity.	Color, Plat. standard.	Oxygen consumed.	Nitrogen as: Albuminoid ammonia. Total.	Suspended.	Dissolved.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Sulphuric acid.	Incrusting constituents.	Alkalinity.	Total hardness.	Residue on Evaporation. Total.	Suspended.	Dissolved.	Iron.	Carbonic acid (free and half-bound).
Oct. 16	12 M.	R	12	4	58	7.6	0.212	0.069	0.143	0.033	0.004	0.012	2.0	3	4	22	26	77	7	70	0.5	....
Oct. 16	12 M.	F	12	1	3	1.2	0.074	.....	.....	0.024	0.000	0.080	2.0	11	16	10	26	70	....	....	0.0	....
Oct. 22	12 M.	R	12	4	55	7.6	0.191	0.014	0.177	0.036	0.003	0.013	3.0	3	3	24	27	71	2	69	0.4	10
Oct. 22	12 M.	F	12	0	5	2.1	0.110	.....	.....	0.027	0.000	0.087	3.0	14	14	11	25	69	....	....	0.2	8
Oct. 29	9 A. M.	R	13	5	51	8.7	0.216	0.031	0.185	0.025	0.003	0.020	4.0	3	3	18	21	69	10	59	0.3	8
Oct. 29	9 A. M.	F	14	1	6	2.0	0.143	.....	.....	0.021	0.001	0.093	4.0	9	10	10	20	65	....	....	0.1	13
Nov. 5	9 A. M.	R	10	5	50	7.2	0.205	0.006	0.199	0.025	0.003	0.060	4.0	1	1	25	26	73	7	66	0.4	9
Nov. 5	9 A. M.	F	10	1	3	1.7	0.160	.....	.....	0.009	0.000	0.110	3.8	10	8	12	20	69	....	....	0.0	11
Nov. 26	10 A. M.	R	8	3	43	....	.....	.....	.....	.....	0.002	0.105	3.2	....	0	31	31	73	2	71	0.3	12
Nov. 26	10 A. M.	F	9	2	5	....	.....	.....	.....	.....	0.004	0.105	3.2	....	4	27	31	75	....	....	0.1	15
Dec. 4	11 A. M.	R	6	4	45	....	.....	.....	.....	.....	0.003	0.080	3.5	....	20	28	48	70	2	68	0.2	14
Dec. 4	11 A. M.	F	7	1	7	....	.....	.....	.....	.....	0.003	0.085	3.5	....	21	17	48	65	....	....	0.0	14
Dec. 10	2 P. M.	R	5	3	51	....	.....	.....	.....	.....	0.003	0.170	3.5	....	18	26	44	79	2	77	0.2	8
Dec. 10	2 P. M.	F	5	1	6	....	.....	.....	.....	.....	0.003	0.220	3.5	....	31	13	44	75	....	....	0.0	10
Dec. 17	10 A. M.	R	3	75	70	7.1	0.135	0.060	0.075	0.033	0.004	0.095	2.5	3	7	10	17	88	23	65	0.3	10
Dec. 17	10 A. M.	F	3	1	4	1.2	0.039	.....	.....	0.018	0.001	0.160	2.5	22	....	9	....	56	....	....	0.0	16
Dec. 24	12 M.	R	3	9	40	5.1	0.019	0.003	0.016	0.008	0.000	0.080	2.0	3	7	25	32	58	7	51	0.2	6
Dec. 24	12 M.	F	3	0	2	1.1	0.015	.....	.....	0.008	0.000	0.085	1.7	13	9	16	25	49	....	....	0.0	11
Dec. 31	11 A. M.	R	2	4	30	4.7	0.014	0.001	0.013	0.007	0.000	0.160	1.7	3	14	19	33	66	6	60	0.1	6
Dec. 31	11 A. M.	F	2	0	5	1.0	0.011	.....	.....	0.006	0.000	0.160	1.7	17	26	9	35	60	....	....	0.0	11
1903.																						
Jan. 8	10 A. M.	R	5	5	30	3.8	0.012	0.001	0.011	0.002	0.002	0.210	3.0	4	8	17	25	59	7	52	0.2	10
Jan. 8	10 A. M.	F	4	0	2	1.3	0.008	.....	.....	0.002	0.002	0.210	2.8	7	12	12	24	72	....	....	0.0	12
Jan. 14	1 P. M.	R	4	4	26	5.1	0.014	0.002	0.012	0.001	0.001	0.150	3.0	3	7	24	31	64	5	59	0.2	12
Jan. 14	1 P. M.	F	4	0	9	2.0	0.010	.....	.....	0.001	0.001	0.150	3.0	7	10	20	36	70	....	....	0.0	14
Jan. 21	12 M.	R	3	20	28	4.2	0.016	0.002	0.014	0.002	0.003	0.060	4.0	2	3	28	31	70	10	60	0.2	7
Jan. 21	12 M.	F	4	0	6	2.0	0.011	.....	.....	0.006	0.003	0.060	4.2	6	7	24	31	61	....	....	0.0	6
Jan. 28	11 A. M.	R	4	10	40	4.6	0.014	0.002	0.012	0.004	0.004	0.250	3.0	4	5	21	26	59	7	52	0.3	9
Jan. 28	11 A. M.	F	4	0	5	1.8	0.007	.....	.....	0.005	0.004	0.250	3.0	12	13	11	24	51	....	...	0.0	12

On December 17th and 24th, the river-water sample was collected at a place before the application of soda reached the water.

The river water has a vegetable or musty odor, usually very slight; but, occasionally, during the autumn, it was quite pronounced. After filtration the odor in the water is somewhat less than in the river water.

The river water and filtered water contain, approximately, the same quantity of dissolved oxygen. In October the quantity was about 60% of that required for saturation. Since cold weather set in, the water has been nearly saturated with atmospheric oxygen, at times completely so.

Solutions of sulphate of alumina have usually been prepared of 2% strength. When the full plant is in operation stronger solutions will be used. The diluter solutions are now used for purposes of securing a better control in the rate of application with the devices in hand.

The sulphate of alumina is obtained from the Pennsylvania Salt Manufacturing Company, and costs about 1 cent per pound. It contains no free sulphuric acid, practically no sediment, and about 17% of water-soluble aluminum oxide, with traces of iron.

Up to February 1st, the quantity of sulphate of alumina applied to the river water averaged 1.30 grains per gallon. Computed from the filtered water, the quantity was 1.35 grains per gallon. The range in quantity applied was from 0.29 to 2.01 grains, depending principally upon the amount of color and amorphous matter contained in the raw river water. Some evidence of the relation between the required amount of coagulant and the removal of color, bacteria, etc., under different conditions is indicated further on.

Soda.—The alkalinity of the river water became low, as compared with that necessary for the decomposition of the sulphate of alumina required for the treatment of the freshet water, during the latter half of December, and from December 17th to 30th, inclusive, there was applied a solution of soda ash, ranging in quantity from 0.16 to 0.63, and averaging 0.49 grain per gallon. During this period there were numerous occasions when the composition of the river water changed quite rapidly, and for this reason it was considered wise to apply soda in somewhat larger quantities and for a somewhat longer period than would appear to be called for by an inspection of the data in Table No. 4. On these occasions it was imperative that analyses of the river water be made from time to time throughout the entire 24 hours. It was the endeavor to apply soda so that the final filtered water would at all times contain at least 5 parts per million of alkalinity, capable of decomposing more than ½ grain of sulphate of alumina per gallon.

Efficiency of Coagulating Basin.—In Table No. 6 is given a monthly summary of the principal constituents of the river water before and after it passed through the coagulating basin. The average period of coagulation is also noted.

Cleaning the Coagulating Basin.—The coagulating basin was first cleaned on November 10th, when there were about 8 ft. of accumu-

lated sediment or sludge on the bottom. This was removed by draining and pumping out the sludge in the lower portion of the basin, river water being applied from time to time by opening the gates at the bottom of the stand-pipe at the north end. The sludge was liquid in its character, so that it formed apparently a layer of uniform thickness over the entire bottom, excepting perhaps over a limited area near the inlet.

TABLE No. 6.—Summary of Results Showing the Efficiency of the Coagulating Basin.

Month.	Period of coagulation and subsidence.	Turbidity.		Color.		Amorphous Matter.		Bacteria.	
		River water.	Coag. basin eff.	River water.	Coag. basin eff.	River water.	Coag. basin eff.	River water.	Coag. basin eff.
1902.	Hours.								
September.....	3.1	10	6	31	20	.....	.....	5 400	3 900
October.....	3.3	6	5	52	31	1 100	380	3 800	650
November.....	3.2	5	4	45	28	280	80	3 500	1 100
December.....	2.9	7	4	44	24	450	210	5 800	1 800
1903.									
January.....	2.8	6	5	31	21	200	115	4 000	1 700

On January 13th the coagulating basin was again cleaned out, and it was found that there was a layer of sediment about 5 ft. in thickness. The character of this sludge was examined more carefully than on the former occasion, and, from numerous samples, it was found to contain about 87% of water and 13% of dry solids. Of the latter, about 27% was found to be aluminum hydrate; the remainder consisted of the various matters removed from the river water.

There was some decomposition going on in the organic matter of the sludge, as removed, on both occasions, particularly in November, as indicated by the odors in the basin during cleaning. There was no sign, however, of such decomposition as might be classed as a septic action, and the sediment in no place had turned black, as has been noted in some instances, elsewhere.

Method of Washing the Filters.—Numerous studies have been made as to the best rate and pressure for the application of the wash-water, and also the application of air for purposes of agitation, as well as the

period during washing when air can be most advantageously applied. According to the evidence now available, the best procedure is to apply air at the commencement of the washing operation, under a pressure of 3 lbs., at a rate of about 20 to 25 galls. of free air per square foot of filtering surface per minute, and for a period of 3 minutes. At the commencement of the application of the air the water in the filter is drawn down to about 4 ins. above the sand layer, or 8 ins. below the overflow gutters. This is necessary, to prevent loss of sand. Next, there is applied filtered water under a pressure of about 25 ft., measured at the strainer system, at a rate of about 5½ galls. per square foot per minute, equal to about three-fourths of a vertical foot per minute, and continued until the wash-water, as it leaves the filters, is comparatively clean, and sufficiently so to enable the moving particles of sand at the surface of the layer to be readily seen. At this plant the wash-water clears in quite a well-defined manner, and, with a little practice, the attendants have no difficulty in determining when the end point is reached. As a rule, air has been applied a second time for about 1 minute during each washing, followed by the application of wash-water, to remove the air and to clean the sand to the same point as above described. During washing, the sand layer is raised about 3 ins., or to within 9 ins. of the top of the overflow gutter. The quantity of sand lost is very trifling. The average total time required for washing a filter is 12 minutes.

Percentage of Wash-Water Used.—The quantity of wash-water used is estimated from the duration of its application, and numerous observations have been made as to the rate of delivery of the wash-water pump, with the rheostat on the motor set at different points and for different levels of water in the clear-water basin, from which the wash-water pump takes its suction. Further, these measurements are checked repeatedly by noting the rate at which the water rises in the filter tanks and also in a measuring tank at the end of the sewer line into which the discharged wash-water is allowed to flow.

Up to February 1st, the average quantity of wash-water used for the entire plant was 4.2% of the water treated.

Comparisons of the quantity of wash-water required for the so-called normal filters, those of coarse and fine sand, and those operated at high and low rates, are contained in Table No. 7.

TABLE No. 7.—Comparison of the Quantity of Wash-Water Required in the Case of Filters Operated under Different Conditions.

(Averages for 20 weeks.)

Kind of sand.	Rate of filtration.	Percentage of wash-water required.
Normal	High	3.8
	Normal	4.1
	Low	4.4
Coarse	Normal	3.3
Fine	Normal	4.4

Period of Service.—The period of service of the filters, between washings, depends, of course, upon the character of the water as it reaches the sand layers, and, in general, may be said to bear an inverse relation to the percentage of wash-water. Up to February 1st, the total average period of service between washings of the filters was 9.68 hours. The ordinary range in length of runs of the filters has been from about 6 to 18 hours.

TABLE No. 8.—Summary of Results Showing the Effect of Air Agitation During the Process of Washing.

Month.	Normal Filters.		Filters without Air Agitation.	
	Average period of service. Hours.	Percentage of wash-water.	Average period of service. Hours.	Percentage of wash-water.
September	8.16	3.3	9.19	4.2
October	7.92	4.5	6.12	5.7
November	10.51	4.1	7.35	5.3
December	10.76	4.1	9.11	4.0
January	14.31	2.9	12.29	2.7

Effect of Air Agitation.—Filters Nos. 13 and 16, without exception, have been washed without the application of air. It is yet too soon to discuss comprehensively the value of the air, but an inspection of the sand layers of these two filters after washing shows that they contain sufficiently more clogging material than the regular filters to indicate that the air is of benefit. In November these filters gave shorter runs, and required more wash-water, than the so-called normal filters. An

inspection of all sand layers, at that time, with much detail, indicated that there was some fine sand accumulated in the upper quarter of an inch of the majority of the filters. This fine sand was scraped from the surface of each layer. Following that, these two filters, which received no air, became more normal in their operation, as regards the period of service and percentage of wash-water. The data thus far obtained upon this question are given in Table No. 8, showing the average length of service and percentage of wash-water for Nos. 2 and 8, normal filters, and for these special filters, Nos. 13 and 16.

Power Required.—The electric horse-power required for the operation of each of the various devices is indicated in Table No. 9.

TABLE No. 9.

ELECTRIC HORSE-POWER REQUIRED TO OPERATE THE VARIOUS DEVICES.

Motors to Operate.	Rated Horse-Power.
Wash-water pump	75
Blower	45
Chemical feed pump	2
Sludge pump	40
Soda pump	1
Main shafting	10
Effluent gate-valve	5

Removal of Bacteria.—The thoroughness with which the bacteria in the raw water are removed by these filtration works depends essentially upon the quantity of a coagulant applied.

Table No. 4 shows the evidence in the form of daily averages from the commencement of operations to date. By months, the bacterial results, together with the principal information related thereto, are shown in Table No. 10.

During each of the first three months there were quite a number of occasions when the bacteria in the filtered water were somewhat numerous; due, practically without exception, to interruptions in the proper rate of application of the coagulant. As has been stated already, this was due largely to obstruction in the suction of the pumps supplying the orifice tank, in most instances caused by splinters from the barrels containing the sulphate of alumina, and by foreign matters, such as leaves and shavings, getting into the mixing tanks. During this period, when the men were being trained in the operation of the plant,

there were several times when these interruptions were not detected until the coagulating basin had received a considerable quantity of river water insufficiently charged with coagulant. At the present time these matters have very little significance, owing to the familiarity with their work, on the part of the attendants, the use of more efficient screens to keep splinters and other matters from the suction of the pumps and the orifice tank, to the gong which is now rung by a float in the orifice tank whenever the solution becomes interrupted for a time equivalent to less than 1 minute's regular flow, and to the measuring cylinder upon the chemical feed pipe, enabling more accurate control to be made of the rate of application. During the month of December, it was the uniform intention to secure a high degree of bacterial efficiency from the filters, and this was done, with the exception that the samples obtained from the 8th to the 10th of December were affected by an interruption in the chemical feed.

TABLE No. 10.—Bacterial Results and Principal Information Relating Thereto.

(Averages by Months).

Month.	Sulphate of alumina. Grains per gallon.	Turbidity.			Color.			Amorphous Matter.		Bacteria.			
								Standard units per cubic centimeter.		Per cubic centimeter.			
		River water.	Coag. basin effluent.	Filtered water.	River water.	Coag. basin effluent.	Filtered water.	River water.	Coag. basin effluent.	River water.	Coag. basin effluent.	Filt. water.	Percentage removal.
1902.													
Sept.....	0.74	10	6	3	31	20	11	.....	.....	5 400	3 900	190	96.5
Oct.....	1.59	6	5	1	52	31	7	1 100	380	3 800	650	90	97.6
Nov.....	1.63	5	4	2	45	28	7	280	80	3 500	1 100	60	98.3
Dec.....	1.70	7	4	1	44	24	5	450	210	5 800	1 800	50	99.1
1903.													
Jan.....	0.84	6	5	0	31	21	5	200	115	4 000	1 700	110	97.2

During the month of January, lower quantities of coagulant were used intentionally, with the view to seeing the efficiency of different ratios, and, with the uniform rate of application of coagulant, the

bacterial results obtained during that month are of most value for this particular purpose.

Removal of Color.—It has been found, as a result of repeated examinations, especially in noting the appearance of the filtered water in a large porcelain-lined bath-tub, that it is not possible for a consumer to recognize any color when the filtered water contains 10 parts per million or less. A color of 20 parts is also practically unnoticeable to the consumer. These works have been operated with the view of keeping the color below 10 parts. It has been found, however, that the quantity of coagulant necessary to reduce it to that point is practically as great as that required to reduce it to 5 parts.

Table No. 11 shows the monthly average results of the applied coagulant, and the color in the raw and filtered water:

TABLE No. 11.—QUANTITIES OF COAGULANT APPLIED.
(Averages by Months.)

Month.	Sulphate of alumina. Grains per gallon.	Color.	
		River water.	Filtered water.
1902.			
September	0.74	31	11
October	1.59	52	7
November	1.63	45	7
December	1.70	44	5
1903.			
January	0.84	31	5

Special effort is being made to secure data from which may be deduced certain factors indicating the quantity of coagulant required for the proper treatment of the river water in its various conditions. It is yet too soon to discuss these factors.

Removal of Turbidity.—As noted by the record in Table No. 4, the turbidity of the filtered water usually ranges from nothing to 2 parts. Now and then it becomes as high as 3 parts. All these amounts may be properly recorded as traces, and it may be said that for all practical purposes the filtered water has no turbidity.

Removal of Organic Matter.—Based on the average results given in Table No. 5, the removal of organic matter by these filters is shown in Table No. 12.

TABLE No. 12.—Summary Showing the Removal of Organic Matter.

Parts per Million.				Percentage of Organic Matter Removed.	
Nitrogen as albuminoid ammonia.		Oxygen consumed.			
River water.	Filtered water.	River water.	Filtered water.	Albuminoid ammonia.	Oxygen consumed.
0.121	0.075	6.3	1.6	38	75

Removal of Tastes and Odors.—The Passaic River water ordinarily has a slightly musty or vegetable odor, and at times during the autumn it has a swampy odor which is noticeable to persons unfamiliar with the water, but which is not disagreeable, and, in fact, is hardly recognized by those familiar with surface waters from swampy areas. The removal of tastes and odors by filtration is appreciable, but when the swampy odor is present in the river water it is still clearly recognizable in the filtered water on careful examination. Studies of the practicability of removing it by aeration have been made, but it is found that this is unsuccessful, as the odors and tastes still persist after vigorous aeration for some 10 to 12 hours. The tastes and odors are evidently produced by oily substances liberated from the vegetable growths in the swampy areas, and, apparently, could be removed only by filtration through charcoal, by ozonization, or by intermittent filtration through sand at exceedingly low rates.

Removal of Coagulant.—In no case has the filtered water contained any undecomposed sulphate of alumina. Regarding the removal of the aluminum hydrate, ordinarily this is complete, although now and then the numerous analyses made indicate that faint traces of the hydrate in a very fine colloidal form have appeared in the filtered water. These traces are too small to be measured, although, in a general way, it may be said that there are times when it would probably amount to about 0.06 part per million, equal to 0.0035 grain per gallon. The average would be less than 0.01 part per million, corresponding to a removal of more than 99% of the hydrate contained in the raw water. These traces are gradually diminishing as the sand layers are becoming "ripened."

Change in Hardness.—Table No. 13 gives a comparison of the average hardness of the river and the filtered waters.

TABLE No. 13.—Comparative Hardness of the River and Filtered Waters.

Parts per Million.

River Water.			Filtered Water.		
Temporary. (Alkalinity.)	Permanent. (Incrusting constituents.)	Total hardness.	Temporary.	Permanent.	Total hardness.
23	12	35	15	19	34

Effective Size of Sand Grains.—The principal point in relation to the effective size of the sand grains is the importance of removing the fine particles contained in the sand. The specifications, as originally prepared, are none too severe. The effective size, within the range stated (see Table No. 1), and under the local conditions, makes no appreciable difference with regard to the quality of the filtered water, but the coarser sands allow a reduction in the percentage of wash-water used, as shown in Table No. 14.

TABLE No. 14.—Percentage of Wash-Water Required in Filters Containing Different Kinds of Sand Layers.

(Average for 20 weeks.)

Kind of sand.	Percentage of wash-water required.
Fine	4.4
Normal	4.1
Coarse	3.3

Effect of Rate of Filtration.—The rate of filtration, as far as the quality of the filtered water is concerned, does not seem to be a factor of significance. If the applied water is well coagulated, satisfactory results will follow with a rate of filtration at least as high as 185 000 000 galls. per acre per 24 hours, and with an inadequately coagulated water good results cannot be obtained at rates of 80 000 000 galls. per acre per 24 hours, or much less. That the number of bacteria in the filtered water is not materially affected by the rate of filtration is shown by Table No. 15.

TABLE No. 15.—Average Results, Showing Removal of Bacteria by Filters Operated at Different Rates.

(Averages for 20 weeks.)

Rate of filtration.	Rate of Filtration.		Bacteria per Cubic Centimeter.		Percentage of removal of bacteria.
	Gallons per acre daily.	Gallons per square foot per minute.	River water.	Filtered water.	
High	185 000 000	3.0	3 500	100	97.1
Normal	125 000 000	2.0	3 500	90	97.4
Low	80 000 000	1.2	3 500	80	97.7

The more recent results, obtained after the sand layers became ripened, show no appreciable differences.

Compared with the normal rate of 125 000 000 galls. the high and low rates affect the period of service and percentage of wash-water as shown in Table No. 16.

TABLE No. 16.—Average Results Showing the Effect of the Rate of Filtration on Period of Service and Percentage of Wash-Water.

(Average for 20 weeks.)

Rate of filtration.	Period of service. Hours.	Volume of water filtered per run.	Percentage of wash-water.
High	7.52	470 000	3.8
Normal	10.18	425 000	4.1
Low	12.93	358 000	4.4

The larger yield of filtered water between washings by the high-rate filters, apparently, is explained by the deeper penetration into the sand layers of matters removed from the water. Regarding the percentage of wash-water, the actual volume of water required per filter for cleaning does not seem to be exactly proportional to the amount of accumulated matters in the sand layer.

Regarding Costs.—It is not feasible, at the present time, to discuss questions of cost in as much detail as might be desired. However, information upon the principal items in the operation of the works is

contained in the foregoing pages, and the cost of construction per million gallons of nominal daily filtering capacity may be summarized as follows:

Coagulating basin and clear-water basin, including piping within the walls and grading the grounds	$5 400
Supply and suction piping outside the structures	800
Filter tanks, including covers	1 500
Main building and wings, including floors, piers and entire superstructure, except the last item	2 000
Filter equipment, complete, including machinery within the buildings	4 800
Power equipment and outside wiring	800
	$15 300

Acknowledgment.—In closing, the writer desires to record his acknowledgments to J. Waldo Smith, M. Am. Soc. C. E., under whose direction these works were designed and built and are operated, for permission to make use of the data embodied in this paper.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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AUTOMATIC MODULES FOR REGULATING THE SPEED OF FILTRATION.

By Charles Anthony, Jr., M. Am. Soc. C. E.

To be Presented April 1st, 1903.

Now that the importance of keeping the velocity of sand filtration constant, and below a given maximum, while providing the means of gradually increasing that velocity after each cleansing of the sand surface, has come to be universally recognized, it has occurred to the writer that a short paper treating on the various forms of module, or controller, that have been designed with this object might be of interest.

Numerous forms of semi-automatic apparatus of this description have been devised, but as, under the law of the survival of the fittest, they appear to be doomed to speedy extinction, at all events for the purpose in view, it has not been considered expedient to include any special mention of them herein.

Before proceeding further, it may be well to point out the requirements which an apparatus of this nature should fulfil. They are twofold:

1st.—It should be susceptible of adjustment to any constant discharge between the limits zero and the maximum volume required.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

2d.—It should be mechanically simple, and of a durable nature, not requiring skilled attention.

All modules that have been designed by, or have come to the notice of, the writer, of which a list is appended in Table No. 1, belong to one or other of the following four categories:

1st.—A weir or orifice, whether surface or submerged, maintained under a constant head by its own movement.

2d.—A fixed, submerged weir, or orifice, kept under constant relative head.

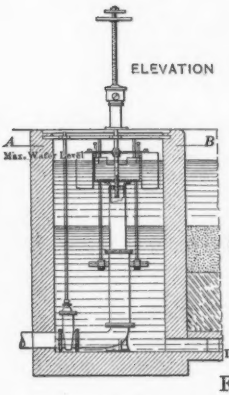
3d.—A governed motor, passing a constant volume at a constant velocity.

4th.—A submerged orifice, closed automatically in such ratio to the head as to give a uniform discharge.

TABLE No. 1.

Description of Module.	Means of Varying the Discharge.
1st Category.	
1. Surface weir supported by float at constant depth	Submergence variable.
2. Surface weir, as above	Width of weir variable.
3. Submerged weir, as above	Submergence variable.
4. Submerged weir, as above	Size of orifice variable.
5. Floating siphon	Head variable.
6. Floating siphon	Size of orifice variable.
2d Category.	
7. Balanced valve, keeping pressure constant on orifice	Pressure variable.
8. Balanced valve, keeping pressure constant on orifice	Size of orifice variable.
9. Head on submerged weir kept constant by relative motion of floats on up- and down-stream sides	Head variable.
10. Head on submerged weir kept constant by relative motion of floats on up- and down-stream sides	Size of orifice variable.

AUTOMATIC MODULES
FOR REGULATING THE SPEED OF FILTRATION.



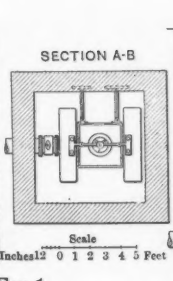
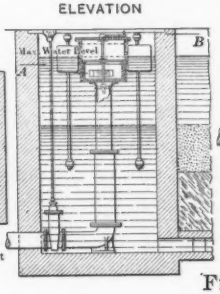


FIG. 1



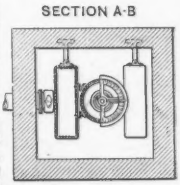
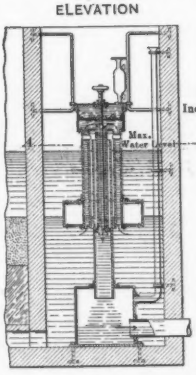


FIG. 2



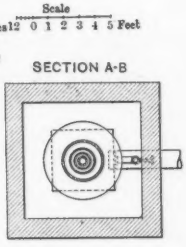


FIG. 3

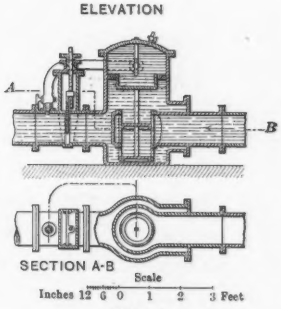


FIG. 4

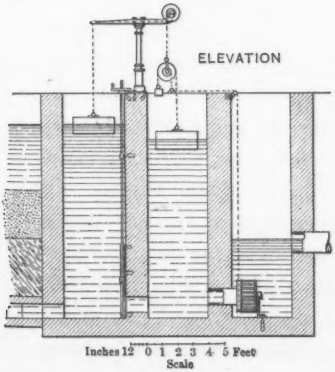


FIG. 5

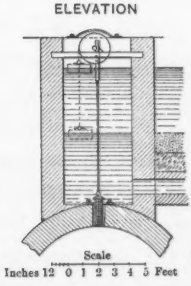


FIG. 6

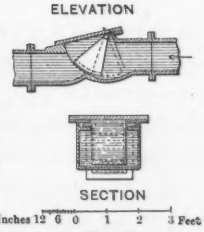


FIG. 7

3D CATEGORY.

11. Turbine or motor, driven by passing water, and governed. Speed variable.
12. Turbine or motor, driven by passing water, and governed. Capacity of motor variable.

4TH CATEGORY.

13. Paraboloid moved in orifice by float ..... Discharge cannot be varied.
14. Disc or sphere moved in paraboloidal tube by float ..... Discharge cannot be varied.
15. Pendulous obstruction moved and varied by velocity of passing water ..... Discharge cannot be varied.
16. Flat, cylindrical or other shaped valve with uniform motion derived from float, but with curved orifice or orifices ..... Variable, in the latter case by closing off one or more orifices.
17. Rectangular aperture or apertures, in flat plate or cylindrical valve, susceptible of two rectilinear, or rotary and vertical movements, one differential and automatic; the other adjustable, to vary discharge.

The most self-evident forms of apparatus for attaining the end required belong to the first class. The Glenfield Jones, a simple surface-weir variety, is illustrated in Fig. 1, and it will be seen that the amount of discharge is regulated by varying the depth of submergence of the weir. This, however, is an imperfect type, as friction causes the weir to be more or less submerged, depending on whether it is floating on rising or falling water, and, furthermore, the adjustment for varying the discharge is cumbersome and inconvenient.

A better arrangement is that which is illustrated in Fig. 2, in which it will be seen that the substitution of a submerged form of weir reduces greatly the error due to friction, since difference of submersion has less effect. The adjustment of the discharge by the closure

AUTOMATIC MODULES,
WITH ADJUSTABLE DISCHARGE.

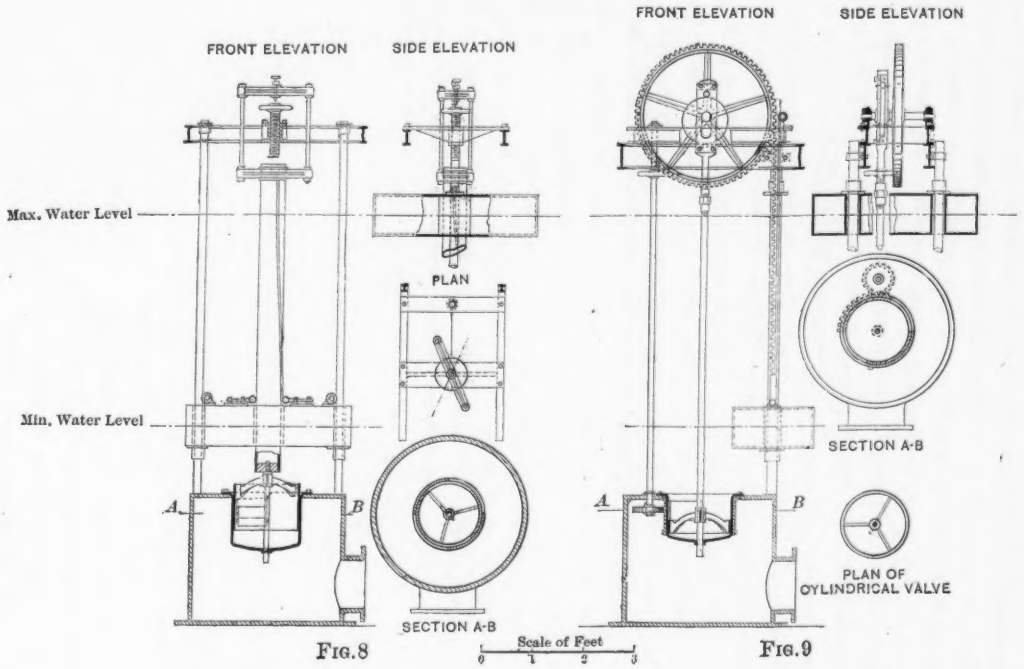


FIG. 8 FIG. 9

of orifices is not only simpler, but lends itself to an easy method of indicating, on a graduated dial, the rate of discharge, seeing that the discharge is directly proportional to the amount of angular movement of the inner cylinder. This end may also be attained, with less friction, by the pneumatic device illustrated in Fig. 3; but the writer cannot say that this appears to him to be a hopeful form, on account of the difficulty of keeping the upper part of the siphon free from air.

To the second category belongs the constant-flow valve of Professor Fleming Jenkins, invented in 1876, of which Fig. 4 is an illustration.

A simpler form has been illustrated and described* by Professor W. R. Burton.

A difficulty encountered when trying a valve of this form, in Buenos Ayres some years ago, was the blithering set up, due to the constant oscillation of the valve about its mean position; but this could doubtless be overcome by a judicious damping arrangement.

Fig. 5 illustrates a somewhat different type of apparatus of the same class, which occurred to the writer on reading of an ingenious form of submerged weir-gauge constructed by Mr. John H. Tudsbery-Turner at the Yokohama water-works.

Class 3 needs no description, nor can the writer call to mind a single case in which this principle has been applied in practice.

A typical example of Class 4 is Juan Ribera's Spanish module, a form of which, designed by the late Mr. J. F. La Trobe Bateman for the City of Buenos Ayres Water-Works, is illustrated in Fig. 6. This would constitute an elegant solution of the problem, did the apparatus fulfil the first condition laid down. Unfortunately, it does not, as it is not susceptible of adjustment for varying the discharge for which it was designed; the popular idea that the discharge may be varied, without affecting the uniformity of the flow, by an initial alteration in the position of the cone in the diaphragm, being a delusion.

Fig. 7 illustrates Appold's module, the action of which depends on the dynamic effect due to variation of velocity. It is, therefore, necessarily inaccurate; and, furthermore, is not susceptible of adjustment for varying the discharge.

What the writer believes to be an original form of module occurred to him in 1893. The fundamental principle of this form consists in

* *Minutes of Proceedings*, Inst. C. E., Vol. cxii, p. 323.

AUTOMATIC MODULES,
WITH ADJUSTABLE DISCHARGE.

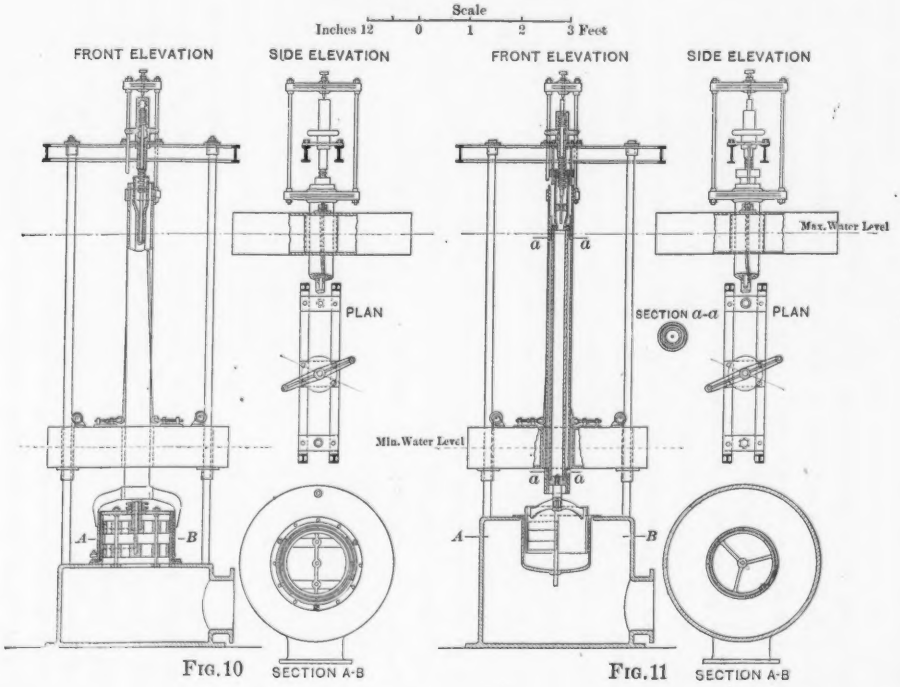


FIG. 10

FIG. 11

the closing of a submerged orifice, or orifices, in two distinct directions, one automatic and differential, the other by hand to set to the discharge required. Fig. 8 shows the form in which the idea first occurred to the writer. It will be seen that the apparatus consists of two almost touching concentric cylinders, on opposite quadrants of each of which are cut two similar rectangular apertures, each occupying a little less than 90° of the circumference. The amount of opening is varied by the float, which causes the inner cylinder to rotate in the ratio of the square root of the head to which they are exposed. This is effected by means of a differential screw, planted or cut on the hollow central shaft, the development of which is part of a parabola. Fig. 9, which has already appeared in the correspondence on the City of Buenos Ayres Sanitary Improvement Works,* is the form which, for constructional reasons, best pleased the then Engineer in Chief of those works, Mr. Charles Nystromer.

It will be observed that the order of movements is the reverse of that which occurs in the first form, and that a cam has been substituted for the differential screw. It should be pointed out, however, that this arrangement, besides entailing greater mechanical complication, labors under the disadvantage of having more moving parts under water.

The form illustrated in Fig. 8 is not theoretically perfect, as in the adjustment for discharge the differential screw is lowered or raised in the guides of the float a distance twice as great as that traversed by the centroid of the apertures. Although this error, in all ordinary cases, is so small as to be negligible, it may be eliminated by either of the devices illustrated in Figs. 10 and 11; in the former by closing the orifices concentrically, in the latter by preserving constant the relative positions of the screw and of the centroid of the apertures.

As a matter of fact, however, the writer does not esteem these devices to be a real improvement on Fig. 8, which is his favorite form, since they entail greater complication, and inevitably give rise to an increase of friction.

As it may be objected that these modules would necessitate tedious calculation and difficult shopwork, in the shaping of the differential screw to meet each special case of change in the maximum and minimum depth of orifice, or range of water level, it may be pointed out

* *Minutes of Proceedings*, Inst. C. E., Vol. cxxiv, p. 86.

that it would suffice to draw out, once for all, the development of the screw (which is a parabola, having its vertex at the center of the aperture), and take that portion of it comprised between the maximum and minimum water levels of the special case under consideration. It will thus be seen that the construction of these modules is no more difficult than that of ordinary sluice-valves, and that, therefore, they can be manufactured and stocked like any other ironwork.

In conclusion, the writer hopes that the foregoing brief analysis of the various forms of automatic module which have come under his notice, or which he has evolved, may be found useful by members of the profession, when designing apparatus of a like nature.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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NOTE ON THE COEFFICIENT OF ELASTICITY OF CONCRETE AND MORTAR BEAMS DURING FLEXURE.*

By Myron S. Falk, Jun. Am. Soc. C. E.

A correct knowledge of the value of the coefficient of elasticity in the case of the flexure of steel-concrete, concrete or mortar beams is a matter of the greatest importance in the designing of beams of this character. The following notes give the results for concrete and mortar beams tested to the point of failure, and are perhaps of more than ordinary value on account of the age of the beams tested.

These beams were square in cross-section, measuring approximately 4 ins. on each side, and were about 38 ins. long. They were first broken by weights applied at the center of 36-in. spans, and then each half of the broken beam was again broken by weights applied at the center of 16-in. spans. The beams were made, during the summer and fall of 1895, by Mr. Adolph Black, Instructor of Civil Engineering in Columbia University, and were tested by the writer, in the Mechanical Laboratory of that University, on an Emery testing machine, in November, 1902.

The beams were four in number. Two were of gravel-concrete and two of mortar. Table No. 1 shows the ratio of gravel and sand to

* This paper will not be presented for discussion at any meeting, but its discussion may be called up at any time, and written communications on the subject are invited for presentation to the Society and for subsequent publication.

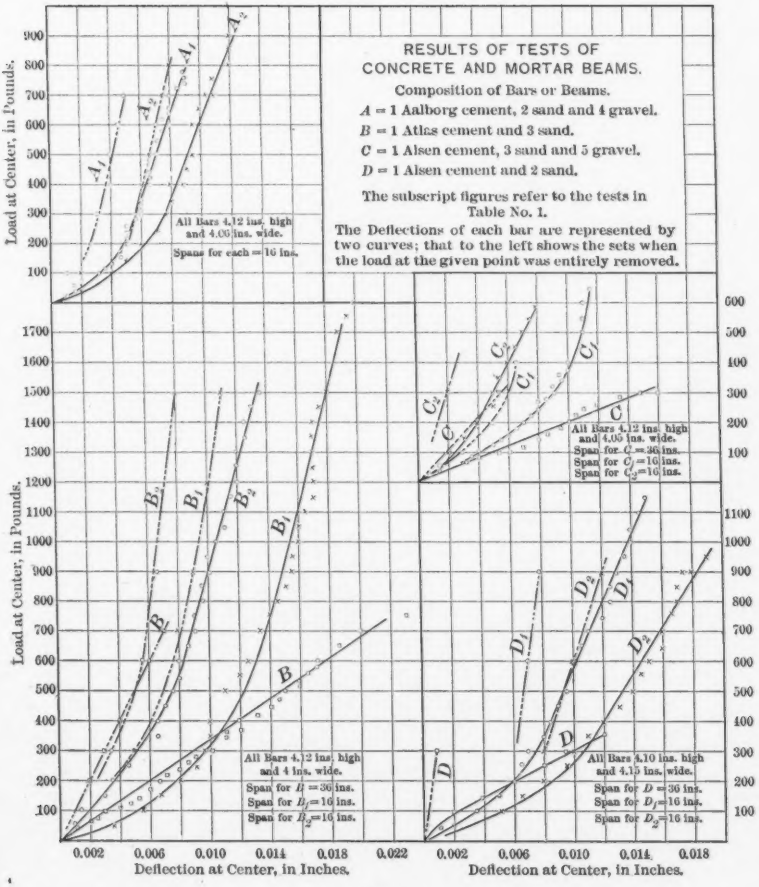

RESULTS OF TESTS OF
CONCRETE AND MORTAR BEAMS.
Composition of Bars or Beams.
A = 1 Aalborg cement, 2 sand and 4 gravel.
B = 1 Atlas cement and 3 sand.
C = 1 Alsen cement, 3 sand and 5 gravel.
D = 1 Alsen cement and 2 sand.
The subscript figures refer to the tests in Table No. 1.
The Deflections of each bar are represented by two curves; that to the left shows the sets when the load at the given point was entirely removed.
All Bars 4.12 ins. high and 4.06 ins. wide.
Span for each = 16 ins.
All Bars 4.12 ins. high and 4.09 ins. wide.
Span for C = 36 ins.
Span for C1 = 16 ins.
Span for C2 = 16 ins.
All Bars 4.12 ins. high and 4 ins. wide.
Span for B = 36 ins.
Span for B1 = 16 ins.
Span for B2 = 16 ins.
All Bars 4.10 ins. high and 4.15 ins. wide.
Span for D = 36 ins.
Span for D1 = 16 ins.
Span for D2 = 16 ins.
Load at Center, in Pounds.
Deflection at Center, in Inches.
0.002
0.006
0.010
0.014
0.018
0.022

FIG. 1.

cement. The sand used was from Cow Bay, Long Island. It was sharp and clean, being entirely free from loam and organic matter. The gravel used was rounded, and varied in diameter from $\frac{1}{2}$ in. to $2\frac{1}{2}$ ins. It was well washed before being used. Three kinds of cement were used, as shown by the table. The usual cement tests showed that the cement was standard in quality. The material was watered to such a consistency that, when solidly rammed in the moulds, water flushed the surface slightly. The material was allowed to remain in the moulds for 3 days, and it set in the air; during the first year the bars were watered at intervals of 10 days or two weeks; during the second year they were watered at intervals of about two months, and after that very intermittently. The bars were never exposed to the weather, being kept during the entire time under cover, in the basement of one of the University buildings. The deflections during the test were measured by a lever deflectometer, reading, by means of a vernier, to the thousandth part of an inch. The instrument was examined for errors before and after the tests, and was found to be correct for the range of readings used.

TABLE NO. 1.

Bar.	Age, in years.	Span, in inches.	Section of Bar, in Inches.		Coefficient of elasticity, in pounds per square inch.	Extreme fiber stress, in pounds per square inch.
			Depth.	Width.		
A	7.4	36	4.12	4.06	.....	....
A_1	7.4	16	4.12	4.06	1 591 000	278
A_2	7.4	16	4.12	4.06	1 102 000	315
B	7	36	4.12	4.00	2 122 000	606
B_1	7	16	4.12	4.00	2 440 000	636
B_2	7	16	4.12	4.00	1 220 000	530
C	7	36	4.12	4.05	1 315 000	247
C_1	7	16	4.12	4.05	387 000	229
C_2	7	16	4.12	4.05	1 023 000	208
D	7.3	36	4.10	4.15	1 165 000	294
D_1	7.3	16	4.10	4.15	597 000	415
D_2	7.3	16	4.10	4.15	597 000	346

Bars A = 1 Aalborg cement, 2 sand and 4 gravel.
" B = 1 Atlas cement and 3 sand.
" C = 1 Alsen cement, 3 sand and 5 gravel.
" D = 1 Alsen cement and 2 sand.

The loads were applied at the intervals shown graphically on the diagrams. At different times the load was entirely removed in order that readings for the permanent deflections might be obtained. The readings were all taken about 15 seconds after the application or removal of the loads.

As shown by the diagrams, the strain of deflection consisted of two parts, one part apparently permanent and one part elastic, the latter disappearing upon the removal of the load. This is shown on the diagram for any one beam by the use of the same letter and subscript on two corresponding or mutually related curves.

The coefficient of elasticity was computed by using the difference between the two deflections thus found; in other words, the elastic deflection was used. This deflection was found to vary almost exactly as the center load, and could be represented by a straight line; no coefficient ef elasticity was computed for a center loading of less than 200 lbs.

The table also gives the values of the extreme fiber stress in the beam at the instant of rupture, the weight of the beam being allowed for in the computations. These values agree, with one or two exceptions, with the results obtained by other experimenters. An attempt was also made, using 4-in. cubes dressed from this material, to obtain a value for the coefficient of elasticity of concrete in compression. The blocks, however, were too small to permit of readings being taken directly from the sides of the specimen, and it was found that there was too much lost motion to permit of measurements being taken between the heads of the testing machine. The attempt to find these values was therefore abandoned. The ultimate resistance to compression of these cubes, when tested with plaster of paris beds, varied from 7 000 to 9 000 lbs. per square inch.

Vol. XXIX. FEBRUARY, 1903. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE SANITARY DISPOSAL OF MUNICIPAL REFUSE.

An Informal Discussion.*

By Messrs. Myron S. Falk, M. N. Baker, W. J. Baldwin and H. de B. Parsons.

Presented at the Meetings of December 17th, 1902, and January 7th, 1903.

Mr. Falk. Myron S. Falk, Jun. Am. Soc. C. E. (by letter).—Many and various have been the methods proposed for the sanitary disposal of municipal refuse. The complete destruction of the material, by means of heat generated by itself or by the aid of heat supplied from extraneous sources, has been the method most advocated. The first case brings into consideration the hope that power may be obtained from this waste material at the time of its destruction. In relation to this, and during this discussion, the plan of producing gas, and thus, indirectly, power, immediately from municipal wastes has not been considered; it is possible that mature reflection may reveal great inherent advantages to be derived from this method of disposal.

In the production of gas, as is well known, water in the form of steam is added to the gases produced from the destructive distillation of coal. It seems not at all unreasonable, therefore, in view of the large percentage of moisture contained in garbage, to expect that the introduction of garbage into a gas producer may not only be a direct saving in the fuel required, but may also obviate the necessity of adding live steam. It is true that, in the ordinary case of gas produc-

*Continued from the *Proceedings* for January, 1903.

tion, it is steam and not wet fuel which is added, but it is not unreasonable to expect that some method can be devised by which garbage may be placed in the producer at such times and in such a manner that its contained water may replace the water which must ordinarily be added. There is but little cause to doubt that such a plan may be put in successful operation, and it certainly seems to offer as great a possibility of obtaining power from wastes as any other plan heretofore proposed. Mr. Falk.

M. N. BAKER, Esq.—It is very evident from the discussions that refuse disposal is a distinctively engineering problem; but, thus far, in America, it has rarely been recognized as such. It is to be hoped that the time is coming—in fact, that it has arrived—when there will be a much needed change, in this respect. There are, in this country, connected with the various companies who are building garbage furnaces or who are establishing reduction plants, comparatively few engineers engaged in the work. Mr. Baker.

It is a significant fact that, whereas our municipalities call in eminent engineers and spend money unstintedly for water supply and sewerage, only on one or two occasions have they called in an engineer to advise them in the matter of garbage disposal, and as far as entrusting to an engineer the whole problem of refuse collection and disposal it is doubtful whether a single instance could be named.

There is the valuable report on the Trenton investigation, mentioned by Mr. Horton, but it is yet to be heard that there have been any decided practical results from it. But, at Trenton, no engineer was called upon until after several years of blundering upon the subject; and, bad as Trenton is, as an example of neglect in this respect, it still remains a shining example of almost the only city in the country that has secured any engineering advice whatever.

One of the cities to adopt garbage cremation recently is Milwaukee. The contract for installing the furnaces provided that the contractor should guarantee that they could be operated with eighteen men, but it is stated that there are 79 or 80 on the pay roll at the present time. It is claimed that this is no fault of the furnaces, being a mere matter of affording employment to municipal laborers; but, however that may be, it serves as an illustration of the unsatisfactory condition of garbage disposal in this country, and of the need of employing engineers to design and operate garbage disposal works.

The low temperature in the Trenton furnaces is remarkable. In recent English installations the aim is to get as nearly as possible to a temperature of 1 800 or 2 000° Fahr. instead of 800 to 1 000 degrees.

Some interesting letters have appeared recently in the London *Electrician*—letters brought out by a paper* by W. F. Goodrich, Assoc.

* "Electricity from Refuse—The Case for the Modern Destructor." A paper read before the Manchester Local Section of the Institution of Electrical Engineers, and published in abstract in *The Electrician* for November 28th, 1902. The letters mentioned appeared in the issues of the same journal for December 5th and 19th, 1902.

Mr. Baker.

Inst. Mech. E., on a combination of refuse destructors (as they call them in England) and electricity works. Several of the writers of these letters, men in some instances who are operating combined refuse destructors and electricity works, have expressed themselves strongly in opposition to such a combination. Certainly, such opposition is a significant fact, and one that should be considered very carefully at the inception of garbage disposal as an engineering problem in this country.

Thus far in the discussion, comparatively little has been said regarding reduction as a means of garbage disposal. To present the subject fairly would take a large amount of time, but attention may be called to a fact which, perhaps, has already been mentioned, but only incidentally, that in all, or nearly all, the larger cities of the United States, which have any improved means of garbage disposal whatever, reduction is being used, and scarcely any of them are using cremation.

TABLE No. 1.—Cities of the United States, Having Populations of 200 000 or More, Where Improved Methods of Garbage Disposal Are Used.

	Population.	Improved means of disposal.
New York	3 437 202	Reduction.
Chicago	1 698 575	None.*
Philadelphia	1 293 697	Reduction.
St. Louis	575 238	Reduction.
Boston	560 892	Reduction.
Baltimore	508 957	None.†
Cleveland	381 768	Reduction.
Buffalo	352 387	Reduction.
San Francisco	342 782	Cremation.
Cincinnati	325 902	Reduction.
Pittsburg	321 615	Reduction.
New Orleans	287 104	None.
Detroit	285 704	Reduction.
Milwaukee	285 315	Cremation.
District of Columbia	278 718	Reduction.
Newark	246 070	None.*
Jersey City	206 433	None.
Louisville	204 731	Cremation.
Minneapolis	202 718	Cremation.

This does not necessarily imply that reduction in this country has been eminently successful and cremation has been a failure, but the figures do show that reduction is at least worthy of serious attention.

* A small quantity of garbage is, or has been, cremated.
† Contract awarded, with the understanding that reduction will be used.

Mr Baker.

All the reduction plants are in the hands of private companies, and comparatively little satisfactory information regarding their financial success is available. Possibly before this discussion is closed it might be feasible to bring out some detailed information from persons familiar with reduction systems. Unquestionably, such information would add very materially to the value of this discussion, in which the many large reduction plants of the country have been virtually ignored.

Statistics, collected by the speaker for his "Municipal Year Book," and revised to date, show that, of the nineteen cities (Table No. 1) of the United States having populations of 200 000 inhabitants or more in 1900, fourteen have some improved means of disposal, and, of these fourteen, ten depend on reduction and four on cremation. In addition, two other places have awarded contracts for final disposal, with the understanding that reduction will be used. Even if the list be extended to include places of 100 000 inhabitants or more, having improved means of disposal, there are but six with furnaces to fourteen with reduction plants, or sixteen of the latter if plants under contract are included. Taking into consideration all places of 3 000 population and more, there were, in 1902, a total of 74 crematories and 22 reduction works, all but three of the latter being in places of more than 40 000 population. Reduction is generally held to be impracticable in small cities, but the figures given show that in the United States that system prevails wherever it is feasible.

Mr. Baldwin.

W. J. Baldwin, M. Am. Soc. C. E.—The speaker is wholly unprepared to talk on the subject of garbage cremation, for the reason that such cremation as he has been doing has been in another direction, *viz.*, either hospital refuse destruction, or waste fuel utilization.

Mr. Soper has suggested the matter of snow melting. There is a great deal of fun in the subject of snow melting, and, were it not that reference to it had been made, the speaker might refrain from alluding to it. The subject is very old, and should be well understood by engineers; still, it comes up, as in the present instance.

When Inspector Williams was made Commissioner of Street Cleaning of New York City, the *Sun* asked why he could not melt the snow off the streets over night, and not leave it to be shovelled and carted when the contractor got ready; and suggested the use of the fire engines of New York for this purpose. Of course, a technical paper would hardly propose such a thing, but Inspector Williams was exercised so much that he asked the speaker if there was anything in the suggestion. The speaker went to Professor Draper, of the Meteorological Department, and ascertained the amount of the snowfall for a certain storm in New York City, and then calculated the street areas, not including the housetops or back yards. A computation showed that it would take all the fire engines in New York City, running day and night, three years to burn coal sufficient to melt that

Mr. Baldwin.

snowfall; that there would be 90 000 tons of coal to haul, and 20 000 loads of ashes left to cart away. The *Sun* would not publish this information, but it appeared in *The American Machinist.* Later, an experiment was made by Mr. Waring, in melting snow, in a manhole in the street, with a coil of pipe and a boiler, which showed the futility of such methods.

Experiences similar to these—steam-heated snow-ploughs, etc.—should set at rest the question of melting the snow, especially with steam, or even with direct fire. The computations were made on the supposition that all the steam generated could be brought in contact with the snow; but, as a matter of fact, in trying to melt snow by any kind of pans, or by blowing steam through it, probably not 10% of the steam would come in contact with the snow, and, in consequence, it would blow away. Again, evaporation will take heat not required for melting. It requires 142 B. T. U. to melt 1 lb. of snow from snow at 32° to water at 32°; but it requires more heat when the snow has a temperature of zero, additional heat to warm the water so that it will not freeze in running off, and heat—a great deal of heat—to vaporize the proportion of the water that will be vaporized.

In regard to particles, or sparks, that appear at the head of a chimney of a crematory, especially at night, they always appear as though they were luminous from heat, but investigation has proved that they were not always so; that immediately over the chimney these particles reflected the light of the chimney, and even when they passed a long distance—probably 20 ft. outside of the axis of the chimney—they would look as if they were afire; whereas, as a matter of fact, it was only the reflected light from the chimney. In an investigation leading to a determination of how far the sparks might fly, it was found that they were not actually sparks at all.

Again, there is the question of what might be done in the way of quenching sparks, assuming that they are sparks. With a chimney 100 ft. high, and having 1 000° of heat, there is a considerable upward push, which might be represented by 2 or 3 ins. of water pressure, and it is possible that something might be arranged at the top of such a chimney by which the sparks, smoke and gases could be given a slight dip into a water tank and thereby cooled.

Mr. Parsons has said that he thought this crematory or destructor could be made to operate without extra fuel. The speaker does not think this would be possible, as there is more than 80% of water in the vegetable and animal matter in garbage. A cabbage will contain more; and all ordinary albuminous compounds—meats and other refuse—contain so much water that the speaker cannot see how it is possible to do without the use of some fuel. Mr. Hering says that the water is evaporated first, or that the moisture is drained off in channels before the garbage is put upon the fire, and is then mixed

with a large quantity of dry refuse—wood, straw, paper, etc.—and also a large quantity of unburned coal. Mr. Baldwin.

In that case, the solution seems to be that there is enough carbon present to evaporate the water, but still, in many cases, there is a great deal of water after the ordinary draining and drying is done. An ordinary dry cabbage contains 80% of water, and the water is very hard to destroy, but, of course, it is necessary to take all the material that comes from hotels and from kitchens, as that is what is to be destroyed. Now, the speaker is satisfied that what is collected in separate receptacles as garbage, in New York City, would contain 80% of water which would not run out by gravitation, and that about 10% of the original would have to be good carbon in order to evaporate the contained water.

The speaker would like to see an apparatus which will burn the ordinary garbage and admixture with dry refuse, or even with ashes. The ashes from an ordinary engineer's department amount to about 20%, by weight, of the coal put in the furnace, but in those ashes there is not 2% of coal. Now, there may be wood enough, in some cases, but, even in New York City, where will the necessary quantity come from?

The speaker can show drawings and furnaces constructed for special work—not primarily for destroying garbage, except in a general way—but is interested in the construction of crematories, and would like to know more about the way to construct a furnace and get along without a primary fire and the addition of fuel.

Another point about cremating garbage, and the utilization of the heat therefrom under boilers, is the formation of various vapors, or gases, which are partially condensable when they strike the heating surface of a boiler. They may contain acids which will injure the boiler tubes to a considerable extent; and, in Europe, where they utilize the heat under boilers, presumably, the boilers are of a very simple type. It would be well for anyone who desires to utilize the heat from garbage and general refuse crematories to study the effect of such gases on the small tube boilers used so extensively in America.

H. de B. Parsons, M. Am. Soc. C. E.—The problem before a City Commissioner, to dispose of the refuse of a municipality, is not always a scientific one. Usually, he has to face a practical problem. In New York City, the fault is due to the form of government and the contract system now in vogue. As a change cannot be made quickly, one has to do the best he can. Mr. Parsons.

The scientific treatments of the wastes of a municipality are fairly well understood. The question is one of engineering; and an engineer who is willing to study the problem can dispose of those wastes in a manner which will be sanitary, provided, of course, that the municipality will give him, or will give the Commissioner, the money to carry out his plans.

Mr. Parsons. The wastes are being disposed of in Europe in a more scientific manner than in this country. The reason, probably, is that action was taken in America without previous scientific study. In Europe, they started with cremation. In America, they followed with cremation; but, as the cremation system adopted was false, failure followed, and, in many localities, public sentiment was set against it. This has been probably the chief reason that cremation is not more generally adopted on this side of the Atlantic.

In Europe, the collections are made and brought to a destructor, where they are cremated; and, in the most successful plants, they are cremated without the use of any fuel whatsoever, beyond the fuel supplied in the garbage and by the other wastes. Each collection district differs in the amount and character of its refuse, but there is sufficient combustible material collected which, when mixed with the garbage, will make it burn in a satisfactory manner.

The object sought, in the most successful plants, is to produce a high temperature; and a plant that will not produce a high temperature is not considered successful.

An incinerator or crematory, as the destructors are called in this country, which has to have a fume or stench cremator, is false in design, or else has that element put into the design in order to meet public sentiment. If the temperature in the burning furnace is sufficiently high, there is no need of a fume cremator. A fume cremator is simply a small fire placed either at the base of the stack, or somewhere in the passage of the gases, the idea being to burn up any fume-creating particles that might pass from the furnace before they reach the outside air.

In Europe, recent practice has not adopted a high stack, many successful furnaces being operated with a short stack and a forced draught. By a short stack is meant one of 70 to 80 ft., although some are still lower. Sufficient height should be given the stack to stop any question as to its being a source of annoyance or a nuisance. The earliest destructors used very tall stacks and natural draught.

Personally, the speaker favors the destruction of municipal refuse by cremation, and believes that it will be generally adopted in this country before a great many years have passed. As indicated before, persons have promoted furnaces, destructors, cremators and incinerators which were not designed scientifically, or have formed companies not strong enough, financially, to carry out their claims. Several cities have recorded failure from both these causes, and in some the destructors are now out of use.

There has been another cause of failure, due to the collection of garbage at the destructor. Garbage, when allowed to collect *en masse*, is extremely offensive; and, unless it is properly taken care of and promptly burned, is apt to create an adverse public sentiment, although the destructor itself may be good of its kind.

Mr. Parsons.

The system of reduction has been adopted by a number of our larger cities because it was easier to organize a reduction plant than a destructor plant. The fear of creating a nuisance—one of the causes most frequently mentioned—has acted to delay progress in the direction of cremation. The same cause, however, was not as active in the case of reduction. The returns from a reduction plant are not sufficient to operate it. Such a plant must rely upon a bonus from the city. The returns from properly constructed destructors, supplied with suitable municipal wastes, should enable the plant to be more than self-maintaining, and to earn a handsome income for the municipality.

It is quite common in Europe to see small towns in which the actual pumping of the water supply is accomplished by means of the steam generated from the heat produced in the destructors. Some towns use the power for electric street-lighting, and others sell the electricity generated. It is perfectly possible to use the heat generated in a manner which will be income-earning, while the reduction plant needs to be sustained by a bonus.

Destructor plants will probably first be started by the smaller towns. On their success, which depends on proper engineering advice, the larger cities will slowly plan future improvements.

The practical problem in any city is the distance from the point of collection to the point of discharge of the carts. In some cities that haul is short, in others it is long. In New York City, some of the carts, the speaker believes, have hauls as long as five miles. A system of collection by automobiles has been discussed, but no automobile has yet been designed which would be sufficiently regular to stand the service. Perhaps, in time, such perfection may be reached as to warrant the collection by this means.

Snow-melting machines cannot handle the snow fast enough. If the carts could be regulated so that they would bring the supply just at the rated capacity of the machines, they might operate in a satisfactory manner; but the trouble is that all the carts arrive together. As they cannot stand in line with their loads of snow, they have to dump it, and if the machine cannot take it it is simply dumped on the street, which is just what is not wanted. When snow has lain in the street a little while, it becomes mixed with dirt and is then difficult to melt. Snow-melters have not proved economical, either in time or money.

If the snow is collected from the streets of New York City promptly, there is little objection to its being dumped in the river, as the snow is very clean. A great drawback has been the lack of docks from which snow could be dumped.

While Mr. Soper's remarks are interesting, some of his statements scarcely give due weight to the practical conditions as they exist in the City of New York.

Mr. Parsons. The speaker is sure that anyone studying the conditions as they exist in this city would conclude that the problem is less scientific than practical. In order to turn the practical problem into a scientific one requires time, and in time it will probably be done.

What all cities and all municipalities need is a co-operation between the different departments. The present Commissioner of the Department of Street Cleaning has done more than any other Commissioner in this direction. A Commissioner is hampered by the General City Government, of which he is but a part. The failure of some of the former administrations, to clean the streets and dispose of the refuse properly, may not have been due solely to the Commissioners.

No criticism of Mr. Soper's purpose is intended. His remarks seem to be misleading to members who have not made a specific study of the subject. His criticism of some of the former Commissioners is a little severe. While the results may have been as stated, it is possible that the Commissioners did not have the power to remedy those conditions.

The garbage of New York City contains an enormous amount of water, and the worst class of all to burn is the stuff collected from the fruit markets, as it is practically non-combustible, except by strong aids. Ordinary offal or kitchen garbage will burn reasonably well when mixed with the other wastes.

The rubbish collections in New York City are 95% combustible; the ashes from the private houses and small apartment houses contain about 20% of unburned coal. If the rubbish collections and the ash collections from private houses and small apartment houses are mixed with the garbage, the whole can be burned in a suitable furnace.

The ashes from the steam-heating companies and large manufacturing plants, known as "steam ash," are collected and brought to the dumps in separate vehicles, so that there is no necessity at any time of ever passing such ash through a destructor, because that ash is practically pure.

In Europe, the principal system of collection is one of non-separation. They simply collect the whole of the refuse, and this, just as it comes, goes into the destructor.

Most destructors contain some form of what is called a "drying table." The material as collected, either wet by contained moisture, or wet by rainfall, is placed first upon some part of the cell or furnace where it can be warmed, and is gradually passed back over the fire, in a manner similar to the coking method of firing. When the material has become dry, it is forced back to the hottest part of the grate, where it burns rapidly, supplying heat to dry the incoming material, while sufficient heat is left to evaporate, in boilers, according to the material burned, from 1 to 2 lbs. of water per pound of refuse.

PROCEEDINGS

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MARCH, 1903.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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March 4th, 1903.—The meeting was called to order at 8.50 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 96 members and 28 guests.

The minutes of the Annual Meeting, and of the meetings of February 4th and 18th, 1903, were approved as printed in *Proceedings* for February, 1903.

Messrs. R. A. MacGregor and F. F. Harrington were appointed tellers to canvass the vote on the proposed amendment to the Constitution.

A paper entitled "A High-Voltage Power Transmission," by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., was presented by the Secretary, and discussed by Messrs. F. O. Blackwell, P. H. Thomas, W. B. Potter and J. R. McKee.

The tellers appointed to canvass the ballots on the proposed amendment to the Constitution, relating to the method of election of members,* reported as follows:

Total number of ballots received		447
Not entitled to vote	2	
Ballots not signed	9	
		11
		436
Voted aye	401	
Voted nay	26	
Blank	9	
		436

The President announced that the proposed amendment was carried, as it had received an affirmative vote of more than two-thirds of all ballots cast, as provided by the Constitution (Sec. 5, Art. IX).

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

FRANK HARVEY ENO, Columbus, Ohio.
HARRY FOOTE HODGES, Washington, D. C.
WILLIAM BENJAMIN JACKSON, Madison, Wis.
ALBERT FERDINAND REICHMANN, Chicago, Ill.
JUNNOSUKE YAMAGUCHI, Kobe, Japan.

AS ASSOCIATE MEMBERS.

MAURICE FRITCHLEY BROWN, Boston, Mass.
GEORGE EDWARD HOWE, Glens Falls, N. Y.
ARTHUR BENJAMIN ILSLEY, Boston, Mass.
FREDERIC ARNOLD KUMMER, New York City.
WILLIAM SUTTON MCFETRIDGE, Parkersburg, W. Va.
TAKEJIRO SHIMA, New York City.
ALBERT FRANKLIN SICKMAN, Holyoke, Mass.
EVERETT BROOMALL WILSON, Newark, N. J.

The Secretary announced that at the meeting of the Board of Direction, March 3d, 1903, the reconsideration ballot, on the application of Frank Taylor Chambers, Assoc. M. Am. Soc. C. E., for transfer to the grade of Member, was canvassed, and that Mr. Chambers was elected a Member.

*See *Proceedings*, Vol. XXIX, p. 36.

The Secretary announced the election of the following candidates by the Board of Direction on March 3d, 1903:

As Juniors.

Bruce Borland, Three Lakes, Wis.
Charles Frank Class, Philadelphia, Pa.
John Clausnitzer, New York City.
Rossiter Raymond Fernow, Ithaca, N. Y.
Harry Macy Harps, Fort Dodge, Iowa.
Caleb Hyatt, Scarsdale, N. Y.
John Douglas Matheson, New York City.

Adjourned.

March 18th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 126 members and 17 guests.

A paper entitled, "Sand-Blast Cleaning of Structural Steel," by George W. Lilly, Assoc. M. Am. Soc. C. E., was presented by the author.

Written discussions on the paper from Messrs. Charles E. Fowler, William A. Polk and J. P. Snow were presented by the Secretary.

The subject was discussed verbally by Messrs. Theodore Belzner, Theodore Paschke, A. H. Sabin, Henry B. Seaman and the author.

The Secretary announced the death of the following members:

Alfred L. Rives, elected Member September 4th, 1872; died February 27th, 1903.

Benjamin Harrison Flynn, elected Junior October 2d, 1900; died March 1st, 1903.

William Buel Franklin, elected Member April 1st, 1874; died March 8th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 3d, 1903.—8.35 P. M.—President Noble in the chair; Chas. Warren Hunt, Secretary, and present, also, Messrs. Briggs, Craven, Croes, Davison, Knap, Kuichling, Osgood, Pegram, Schneider and Wilgus.

The seven geographical districts, into which the membership of the Society is divided, were established for the next year, the same as in 1902.

The resignation of E. H. Goodman, Assoc. Am. Soc. C. E., was accepted.

The following Committee to take charge of the local arrangements for the Thirty-fifth Annual Convention, to be held at Asheville, N. C., was appointed: Messrs. J. L. Ludlow, William Cain, George W. Frank, William Moncure, J. Imbrie Miller, W. B. W. Howe, Arthur Pew, E. T. D. Myers, Wilbur F. Foster, J. A. Montgomery.

Ballots on the reconsideration of the ballot on the application of Frank T. Chambers, M. Am. Soc. C. E., for transfer to the grade of Member, were canvassed, and Mr. Chambers was elected a Member.

Applications were considered, and other routine business transacted.

Seven candidates for admission as Junior were elected.*

Adjourned.

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* See page 101.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, April 1st, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E.; and "Automatic Modules for Regulating the Speed of Filtration," by Charles Anthony, Jr., M. Am. Soc. C. E. These papers were printed in *Proceedings* for February, 1903.

Wednesday, April 15th, 1903.—8.30 P. M.—At this meeting a paper, by Sherman M. Turrill, Assoc. Am. Soc. C. E., entitled "An Investigation of the Properties of Brick Under Different Physical Conditions," will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, May 6th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "A Small Rock-Fill Dam," by H. deB. Parsons, M. Am. Soc. C. E.; and "Deflection of Beams with Variable Moments of Inertia," by C. W. Hudson, M. Am. Soc. C. E. These papers are printed in this number of *Proceedings*.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention of the Society will be held at Asheville, N. C., during the week beginning June 8th, 1903. The following have been appointed as a Local Committee of Arrangements:

J. L. Ludlow,

William Cain,	W. B. W. Howe,
George W. Frank,	Arthur Pew,
William Moncure,	E. T. D. Myers,
J. Imbrie Miller,	Wilbur F. Foster,

J. A. Montgomery.

TOPICS FOR DISCUSSION AT THE ANNUAL CONVENTION.

At the last four Annual Conventions no formal papers have been presented, but, instead, topics of general interest have been discussed. The interest which these discussions have aroused has shown that they are appreciated, and, for the coming Convention, the Committee on Publications would be glad to receive from members suggestions as to suitable topics.

The following list, of the subjects which have already been discussed at Conventions, is here printed, in order to give some idea of the kind of subjects desired:

List of Subjects Presented for Discussion at the last four Annual Conventions.

" Should the use of the method of Wheel Concentrations be discontinued in determining the Stresses in Railroad Bridges?
" In view of present knowledge of the Effect of Repeated Applications of Load, should Fatigue Formulas be used in Bridge Design?
" (*a*) Should Stream Contamination by the Sewage of Cities be absolutely probibited by law?
" (*b*) Should the Purification of the Sewage of Cities be compulsory, and is this feasible for Large Cities?
" (*c*) Is Filtration the coming solution of the Pure-Water Question for Cities?
" What is the Proper Friction Coefficient for use in the design of Riveted Steel Pipe?
" What are the economic conditions under which Electricity may be profitably substituted for Steam in the operation of Branch Railroad Lines, and what are the engineering requirements to be considered in such substitution?
" What is the present development of the so-called Telferage System for moving either Freight or Passengers? What are the conditions under which that System is preferable to movement by Rail, and what is its adaptability to still further application in competition with Rail Lines?

" Height of Buildings.
(1) What considerations should limit the height of buildings?
(2) Do recent developments in construction, sanitation, intercommunication and economy of administration, warrant the removal of all restrictions?
" Recent Practice in Rails.
The progressive increase in weight; the increase in hardness, particularly in carbon; the sections in most general use; the effect of changes in weight, composition and section.
" Filtration of Water for Public Use.
The several processes now used for the removal of objectionable matter; their comparative sanitary effect, cost and reliability.

"Do the interests of the profession, and the duty of its members to the public, require that only those who are competent be allowed to practice as Civil Engineers? Under what authority, through what agency, and upon what evidence of competency, should applicants be admitted to the practice of Civil Engineering?

"Steel-Concrete Construction.

What stress in tension and compression should be allowed in concrete?

What is the proper modulas of elasticity of concrete?

In Steel-Concrete Arches:

(1) What should be the ratio of steel section to concrete section, and what is the best form and disposition of the former?

(2) What consideration should be given to temperature changes and consequent stresses?

(3) What are the best proportions for concrete, and what is the best method of placing it?

"The Decolorization of Water.

When is it necessary? How may it be accomplished?

"The Consumption of Water in Municipal Supplies and the Restriction of Waste.

"In contract work, either public or private, is it preferable to make separate contracts for the different branches of trades involved, or to combine all under one general contract?

"Is it possible and desirable to keep accounts of work in progress in such a manner as to ascertain unit costs on each class of work?

"Is steel susceptible of being made as permanent a building material as masonry?

"In view of the numerous disasters caused by the contracting of channels, or the damming of small streams, should non-navigable streams be under the control of the National Government?

"Should the National Government undertake the construction and operation of irrigation works?

"Should Engineering Practice be regulated by a code of ethics? If so, how can such a code be established?"

ACCESSIONS TO THE LIBRARY.

From February 11th to March 10th, 1903.

DONATIONS.*

LATHES, SCREW MACHINES, BORING AND TURNING MILLS.

A Practical Treatise on the Design and Construction of Turning Machines, Including Lathes, Automatic Screw Machines, Boring and Turning Mills, and their Accessories. By Thomas R. Shaw. Cloth, 9 x 6 ins., 10 + 649 + 5 pp., illus. The Scientific Publishing Company, Manchester, 1903. 15 shillings, net.

The object of this work is to review in detail types of the many varied machine tools in use for the working into shape of metals, and to give constructive details of the more important mechanisms and devices, which, it is hoped, will prove helpful to those engaged in various branches of engineering, and make easier the solution of problems in design which are presenting themselves continually in various guises in everyday practice. It was considered that the best way to treat the subject would be to give examples from actual practice, showing the different mechanisms with their respective constructional surroundings. This plan has been adopted as far as practicable. The Contents are: General Notes on Design and Arrangement; Principle of the Lathe; Small Lathes with Some Special Features; On Screw Threads; American Lathes; Lathes for Special Purposes; Small Lathes for Accurate Work; Electrically-Driven Lathes; Summary of Lathe Design; Turret Lathes; Examples of Hollow Turrets; Vertical Turret Lathes; Full Automatic Screw Machines; Heavy Lathes; Boring and Turning Mills. There is an index of five pages.

IRON AND STEEL, IRON ORE, AND COAL STATISTICS FOR THE UNITED STATES, GREAT BRITAIN, GERMANY, FRANCE, AND BELGIUM.

Revised to the end of 1901. By James M. Swank. Cloth, 6 x 4 ins., 32 pp. Philadelphia, The American Iron and Steel Association, 1902.

This compilation of Iron and Steel, Iron Ore, and Coal Statistics for the United States and four European countries is presented to the members of the American Iron and Steel Association as a souvenir of the completion of the author's thirty years of continuous service, first as Secretary and afterwards as General Manager of the Association. The pamphlet also contains the production of iron ore in Algeria as far back as authentic statistics are available, the production of coke in the United States to the close of 1901, and of the shipments of Connellsville and Pocahontas Flat Top Coke, statistics of the shipments of Lake Superior iron ore and of Cuban iron ore to the same date; also complete statistics of the imports of iron ore into the United States at the close of 1901.

ENGINEERING CONTRACTS AND SPECIFICATIONS

Including a Brief Synopsis of the Law of Contracts, and Illustrative Examples of the General and Technical Clauses of Various Kinds of Engineering Specifications. Designed for the Use of Students, Engineers, and Contractors. By J. B. Johnson, M. Inst. C. E., M. Am. Soc. C. E., M. Am. Soc. M. E. Third Edition Revised. Cloth, 9 x 6 ins., 566 pp., por. Engineering News Publishing Co., New York, 1903. $6.00.

The preface states that in the present edition a general revision of Part IV has been made, in addition to minor changes in the other portions of the book. Several complete specifications have been entirely changed, or replaced, and many new ones have been added. Two new appendices are given on The Engineer as an Expert Witness, and the Standard Specifications for Iron and Steel proposed by the American Committee of the International Association for Testing Materials. By these additions the book has been enlarged 114 pages. The Parts are: Synopsis of the Law of Contracts; Engineering Specifications and Accompanying Documents; Specific Descriptive, or Technical Clauses in Specifications; Illustrative Examples of Complete Contracts and Specifications. There is an index of six pages.

* Unless otherwise specified, books in this list have been donated by the Publishers.

STATICS BY ALGEBRAIC AND GRAPHIC METHODS.

Intended Primarily for Students of Engineering and Architecture. By Lewis J. Johnson, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6 ins., 8 + 133 pp., 6 plates, illus. New York, John Wiley & Sons, 1903. $2.00.

It is stated in the preface that this volume has been written in the hope of helping students to acquire a knowledge of statics which will include the power to apply it correctly in professional work. To this end an attempt has been made to carry out several specific purposes, among which are the following: 1. To give much attention to the starting points of the science, and to make as clear as possible the course of deduction therefrom. 2. To point out the inherent mathematical limitations of pure statics, and to show how all its important problems are solved. 3. To develop algebraic and graphic methods of solution side by side, and with equal thoroughness. 4. To present a graded set of problems illustrating not only universal principles, but also how statics is used in engineering practice. The chapter headings are: Definitions and Preliminaries; Notation and Conventions; Parallelogram of Forces and its Derivatives; Algebraic and Graphic Statements of the Condition of Equilibrium, with Applications; Scope of Pure Statics; Solutions of Statical Problems; Additional General Topics and Processes; Centers of Gravity; Stress; Structures; Stresses in Non-Framed Structures; Stresses in Framed Structures; Additional Topics and Examples.

LIME AND CEMENT INDUSTRIES OF NEW YORK.

By Heinrich Ries. Chapters on the Cement Industry in New York. By Edwin C. Eckel. Cloth, 10 x 7 ins., pp. 641–968, 102 plates. Albany, University of the State of New York, 1901. (Bulletin of the New York State Museum, No. 44, Vol. 8. November, 1901.) (Donated by F. J. H. Merrill.)

The Contents are: Origin of Limestone; Chemical Composition; Geologic Occurrence; Prospecting; Color of Limestone; Mineralogic Composition; Uses of Limestone; Uses of Lime; Cement; Geology of New York Limestones; Limestone Occurrence by Counties; Cement Industry in New York State; Producers of Lime and Natural Cement; Producers of Natural Rock Cement; History of the Portland Cement Industry in New York State; Manufacture of Portland Cement in New York State; Tests of Cements, Made by the State Engineer, 1897–1900; Key to Tables of Limestone Analyses; Tables of Limestone Analyses. There is an index of ten pages.

Gifts have also been received from the following:

Am. Soc. Mech. Engrs. 1 pam., 3 bound vol.
Assoc. Amicale des Anciens Élèves de l'École Centrale. 1 vol.
Assoc. of Ry. Supts. of Bridges and Buildings. 1 pam.
Augusta, Ga.—City Council. 1 pam.
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Boggs, John I. 3 bound vol.
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U. S. Bureau of Statistics. 1 bound vol.
U. S. Commr. of Education. 1 bound vol.
U. S. Corps of Engrs. 28 specif.
U. S. Interstate Commerce Comm. 1 pam.
U. S. Office of Naval War Records. 7 pam.
Victoria—Water Supply Dept. 1 bound vol.
Webster, Albert L. 1 bound vol.
Young Men's Christian Assoc. of N. Y. 1 pam.

BY PURCHASE.

Der Brückenbau. Von Franz Tschertou. Wiesbaden, C. W. Kreidel, 1903.

Konstruktionslehre der einfachen Maschinenteile. Von O. v. Grove. 2 vol. Leipzig, S. Hirzel, 1902.

Das Eisenbahngleis. Von A. Haarmann. Kritischer Teil. Leipzig, Wilhelm Engelmann, 1902.

Der Praktische Maurer. (Maurer- und Steinmetzarbeiten). Ein Hand- und Nachschlagebuch aus der Praxis für die Praxis. Von Dr. E. A. Menzel. 12. vielfach verbesserte und vermehrte Auflage. Herausgegeben von Otto Alisch, A. Eckardt, Martin Köster, P. Schmidt. Leipzig, I. I. Arnd, 1902.

Elasticität und Festigkeit. Die für die Technik wichtigsten Sätze und deren erfahrungsmässige Grundlage. Von C. Bach. Vierte, vermehrte Auflage. Berlin, Julius Springer, 1902.

Experimental Engineering and Manual for Testing. For Engineers and for Students in Engineering Laboratories. By Rolla C. Carpenter. Fifth Revised and Enlarged Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1902.

SUMMARY OF ACCESSIONS.

From February 11th to March 10th, 1903.

Donations (including 8 duplicates)	97
By purchase	7
Total	104

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
CHAMBERS, FRANK TAYLOR		
Civ. Engr., U. S. Navy, U. S. Navy Yard, Philadelphia, Pa	Assoc. M.	April 6, 1898
	M.	Mar. 3, 1903
COOLEY, MAURICE WURTZ		
Mgr., The National Contr. Co., 246 First St., Cambridge, Mass	Assoc. M.	Mar. 7, 1894
	M.	Dec. 3, 1902
DATESMAN, GEORGE ELVIN		
Prin. Asst. Engr., Bureau of Surveys, 416 City Hall, Philadelphia, Pa		Feb. 4, 1903
HODGES, HARRY FOOTE		
Maj., Corps of Engrs., U. S. A., 1812 N St., N. W., Washington, D. C		Mar. 4, 1903
JACKSON, WILLIAM BENJAMIN		
Madison, Wis		Mar. 4, 1903
RANDOLPH, ISHAM		
Chf. Engr., San. Dist. of Chicago, Room 1010, Security Bldg., Chicago, Ill		Feb. 4, 1903
REICHMANN, ALBERT FERDINAND	Jun.	April 30, 1895
Asst. Engr., Western Div., Am. Bridge Co., 1318 Monadnock Bldg., Chicago, Ill	Assoc. M.	Oct. 5, 1898
	M.	Mar. 4, 1903

ASSOCIATE MEMBERS.

BROWN, MAURICE FRITCHLEY		
Chf. Engr.. Boston Bridge Works, 47 Winter St., Boston, Mass		Mar. 4, 1903
BRYNN, PER		
Care, Am. Bridge Co., 51st St., Pittsburg, Pa		Feb. 4, 1903
HOWE, GEORGE EDWARD		
Asst. Engr., Hudson River Water Power Co., Glens Falls, N. Y		Mar. 4, 1903
HOWE, JOSEPH MILTON		
Houston, Tex		Feb. 4, 1903
MCFETRIDGE, WILLIAM SUTTON		
Asst. Chf. Engr., Little Kanawha R. R. Co., Parkersburg, W. Va	Jun.	May 3, 1898
	Assoc. M.	Mar. 4, 1903
PAINE, HIBBARD ATWILL		
Res. Engr., C., O. & W. R. R., Chandler, Okla. T		Feb. 4, 1903
ROSS, THOMAS ALEXANDER		
Engr. in Chg., Shanghai Woosung Ry. Extension, Box 185, British P. O., Shanghai, China		Dec. 3, 1902
SICKMAN, ALBERT FRANKLIN		
Holyoke, Mass		Mar. 4, 1903

	Date of Membership
STAYTON, EDWARD MOSES	
423 East Kansas St., Independence, Mo	Feb. 4, 1903
WICKES, EDWARD DANA	
Min. Engr., The Low Moor Iron Co. of Va., Low Moor, Va	Dec. 3, 1902
WILSON, EVERETT BROOMALL	
200 Peshine Ave., Newark, N. J	Mar. 4, 1903

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Fort Worth, Tex	Feb. 3, 1903
CLASS, CHARLES FRANK	
2610 North Jessup St., Philadelphia, Pa	Mar. 3, 1903
CROOK, JOHN ANTHONY	
Chf. Engr., The John Gilligan Co., Falls City, Nebr.	Feb. 3, 1903
HYATT, CALEB	
Scarsdale, N. Y	Mar. 3, 1903
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Care, H. A. Sumner, Majestic Bldg., Denver, Colo	Feb. 3, 1903
QUANZ, RUDOLPH	
507 Central Ave., Brooklyn, N. Y	Sept. 2, 1902
SMITH, GEORGE EDSON PHILIP	
Prof. of Physics and Eng., Univ. of Arizona, Tucson, Ariz.	Feb. 3, 1903
STEPATH, CHARLES UNDERHILL	
154 West 122d St., New York City	Feb. 3, 1903
WALKER, EDWARD LLOYD	
Care, Jersey City Water Supply Co., 158 Ellison St., Paterson, N. J	Feb. 3, 1903

CHANGES OF ADDRESS.

MEMBERS.

BARBER, WILLIAM DAVIS.....Asst. Engr. in Chg., Div. of Constr. and Repairs, 323 City Hall, Chicago, Ill.

BEARDSLEY, JAMES WALLACE .....Cons. Engr. to the Comm., and Chf. of the Bureau of Eng., Palace, Manila, Philippine Islands.

COOMBS, STEPHEN ELBRIDGE.....4025 McPherson Ave., St. Louis, Mo.
DAVIS, CHARLES E. L. B.....Lt.-Col., Corps of Engrs., U. S. A., Chf. Engr. Officer of the Div., Manila, Philippine Islands.
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MACNAUGHTON, JAMES.....Care, MacIntyre Iron Co., 26 Cortlandt St., New York City.
MILLER, CHARLES HENRY.....Engr. with McClintic-Marshall Const. Co. of Rankin, Pa.; 727 East End Ave., Pittsburg, Pa.
PARKER, HAROLD .....South Lancaster, Mass.
PEW, ARTHUR.....Auburn, Ala.
SMITH, WILLIAM CHARLES.....With Richards-Lundeen Co., Gen. Contrs., Minneapolis, Minn.
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VALUE, BEVERLY REID.....Care, Toronto & Niagara Power Co., Niagara Falls, Ont., Canada.
WATSON, WILLIAM PARSONS.....Prin. Asst. Engr., Mo. Pac. Ry. Co., St. Louis, Mo.
WEBB, GEORGE HERBERT.....Asst. Engr., Michigan Central R. R., Kalamazoo, Mich.
WILLIAMS, CYRUS JOHN RICHARD..Engr., Lyttelton Harbour Board, Christchurch, New Zealand.
YATES, PRESTON KING.....First Asst. Engr., The Lake Shore & Michigan Southern R. R., 67 Spangler Ave., Cleveland, Ohio.

ASSOCIATE MEMBERS.

BANCE, CHARLES WILLIAM.....Asst. Engr., Jersey City Water Supply Co., 156 Ellison St., Paterson, N. J.
BOGGS, JOHN INNERARITY.....Chf. Engr., Arkansas Southwestern Ry., Gurdon, Clark Co., Ark.

BORIGHT, WILLIAM PARSONS.....Care, T. H. Riddle Constr. Co., Ravenna, Ohio.

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NICHOLS, HENRY FRANCIS.....Gen. Mgr. and Engr., James Hill & Sons, 63 Grenfell St., Adelaide, South Australia.

NOBLE, FREDERICK CHARLES.....439 West 123d St., New York City.

OLBERG, CHARLES REAL.....Asst. Engr., U. S. Geological Survey, Washington, D. C.

PHILLIPS, HOWARD CRATHORNE....Engr., Western Grand Div., A., T. & S. F. Ry., La Junta, Colo.

ROSEWATER, WILLIAM MARCUS....Chf. Draftsman, The Bucyrus Co., Gen. Delivery, Pittsburg, Pa.

SCHENK, CARL LOUIS EDUARD.....Contr. Engr., Exeter Machine Works, Rural Route No. 2, Oakdale, Pa.

TABER, GEORGE AYMAR.....Asst. Engr., Rapid Transit R. R. Comm., 312 West 122d St., New York City.

TURNER, GEORGE DALLAS BAIRD...Vice-Pres. and Gen. Mgr., J. I. C. Mining & Milling Co., 317 Atlas Blk., Salt Lake City, Utah.

ASSOCIATES.

TURRILL, SHERMAN MARSH.....New Milford, Conn.

JUNIORS.

ARMSTRONG, ALEXANDER FLOYD...Office of City Engr., Manila, Philippine Islands.

DIMOND, JAMES RENWICK.....128 West 33d St., New York City.

FULLER, CARL HAMILTON .....Eng. Dept., Koken Iron Works, St. Louis, Mo.

PEARSE, LANGDON.....177 Sixth Ave., Brooklyn, N. Y.

PERRING, HENRY GARFIELD.....Draftsman, Phila. Rapid Transit Co., 619 North 48th St., Philadelphia, Pa.

THOMPSON, WILFORD ASHFORD....Engr., Imperial Constr. Co., Brawley, *via* Imperial, Cal.

RESIGNATIONS.

ASSOCIATES.

	Date of Resignation.
GOODMAN, EDWARD HARRIS	March 3d, 1903

DEATHS.

FLYNN, BENJAMIN HARRISON.....Elected Junior, October 2d, 1900; died March 1st, 1903.

FRANKLIN, WILLIAM BUEL .....Elected Member, April 1st, 1874; died March 8th, 1903.

RIVES, ALFRED L.....Elected Member, September 4th, 1872; died February 27th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(February 11th to March 10th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
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(45) *Mines and Minerals*, Scranton, Pa., 20c.
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PAPERS AND DISCUSSIONS.

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AN INVESTIGATION OF THE PROPERTIES OF BRICK, UNDER DIFFERENT PHYSICAL CONDITIONS.

By Sherman M. Turrill, Assoc. Am. Soc. C. E.

To be Presented April 15th, 1903.

This article is based upon tests conducted in the Civil Engineering Laboratories at Cornell University, during the early part of the year 1901, by the writer, assisted by Professor C. L. Crandall, with suggestions from Professor G. S. Williams.

The methods of procedure, the results of the tests, and the outline of the conclusions are given; and the writer hopes that a complete discussion of the conclusions and a comparison of the work with preceding work in the same line may be brought out.

General Description of the Investigation.

All the brick used in this investigation were common building brick, made at Horseheads, New York, by the Horseheads Brick Company, and were of the usual size (8 x 4 x 2 ins.), but varied, more or less, from these dimensions, being a little less than 4 ins. wide and a little more than 2 ins. thick. In their manufacture a mixture of clay and shale was used, and they were made by the stiff-mud process, under modern methods.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The tests conducted were as follows:

Compressive tests of whole brick on end, edge, and flat, and of brick cubes;

Tension tests;

Bending or transverse tests;

Shearing and torsion tests.

The conditions were:

Natural brick;

Brick filled with water;

Reheated brick.

By "natural brick" is meant brick in its natural condition when placed on the market. By "brick filled with water" is meant brick placed under water for a sufficient period to be thoroughly saturated prior to testing, this condition existing until the test was completed. By "reheated brick" is meant brick which has been subjected to a high temperature after its entrance into the commercial world.

In making the tests for compression, the bearings were ground, and, in addition, plaster of Paris and building paper were used. The cubes were, in general, 2 ins. square, two cubes being sawed from one brick. In the tension and torsion tests, the surfaces were not ground, but building paper was used for a bearing. In the shearing and bending tests, the surfaces were not ground, nor was plaster of Paris or paper used on the bearings.

Purpose of the Investigation.

The object in carrying out these tests was to ascertain the weak points of a brick, and, as brick are subjected to compression, tension, bending, shear and torsion, to a greater or less degree, it seemed best to test them under all these conditions and compare the results.

In testing brick under the three conditions, natural, filled with water, and reheated, the writer had in mind brick used in dry places, brick used in wet places, and brick which were to be used again after having passed through a great fire.

In dealing with brick continually under water, without taking into consideration the effect of freezing, one might question their strength as compared with natural brick. In that part of the investigation, special pains were taken to see that the brick were placed under water for at least 1½ months, so that they should be, as nearly as possible, in the actual condition of brick continually under water.

In the case of reheated brick, as, for example, those which have passed through a great conflagration, there is a question as to the advisability of using such brick, and that was one of the reasons for including this condition in the investigation. In order to bring about this condition, as well as to find the weight of the brick when void of moisture, an oven was built, Fig. 1, Plate XXII, in which the specimens were heated. After the brick were cooled, each one was sounded with a hammer. If it was shaky, it was thrown away; but if it had the ring of a sound brick, it was saved and tested. The question then arose: "Is the hammer test reliable as to the soundness of reheated brick?" The results of these tests show that it is, and that by testing reheated brick with a hammer, about 12% of them were found to be shaky.

PROPERTIES OF THE BRICK TESTED.

Analysis.—The following is an analysis of the brick tested:

Silica	($Si\ O_2$)	64.61 per cent.
Alumina	($Al_2\ O_3$)	20.10 "
Iron oxide	($Fe_2\ O_3$)	6.30 "
Calcium oxide	($Ca\ O$)	6.21 "
Magnesia	($Mg\ O$)	2.50 "
Sulphur trioxide	($S\ O_3$)	trace "
Loss on ignition		0.08 "
Total		99.80 "
Specific Gravity		2.66

Absorption of Water.—In determining the quantity of water absorbed, 500 brick of such varying hardnesses as would represent all grades found in building brick, were first selected. These brick were then placed in the oven shown in Fig. 1. Plate XXII, and were subjected to a high degree of heat, night and day, for one week. At the end of that time it was found that the moisture in the brick had entirely disappeared. Each brick was then taken out of the oven separately and weighed while it still contained its maximum heat, the fire being kept going until every brick was weighed. The weight of each of the 500 brick in the dry state was ascertained by this means.

These 500 brick were next placed under water for about 2 weeks, until they had absorbed all the moisture they could. Each brick was

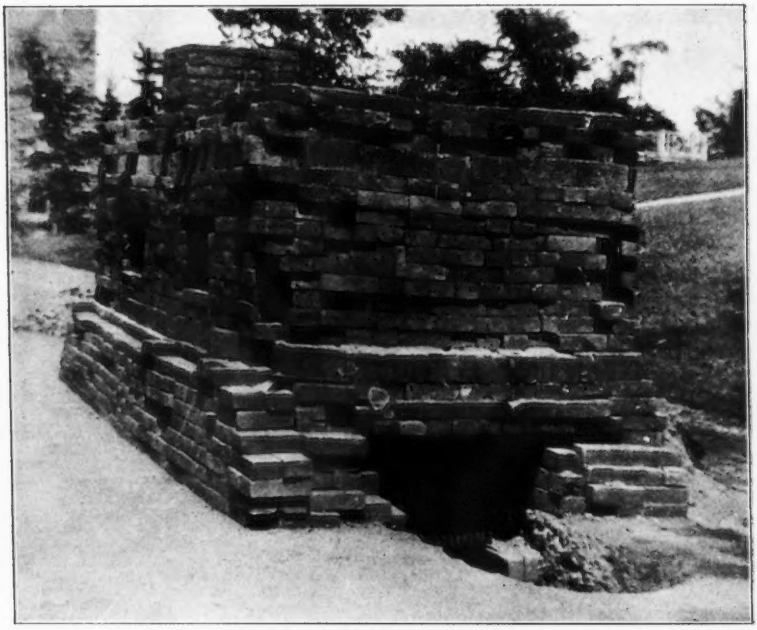


FIG. 1.—BRICK OVEN, WHERE MOISTURE IN BRICK WAS DRIVEN OFF.

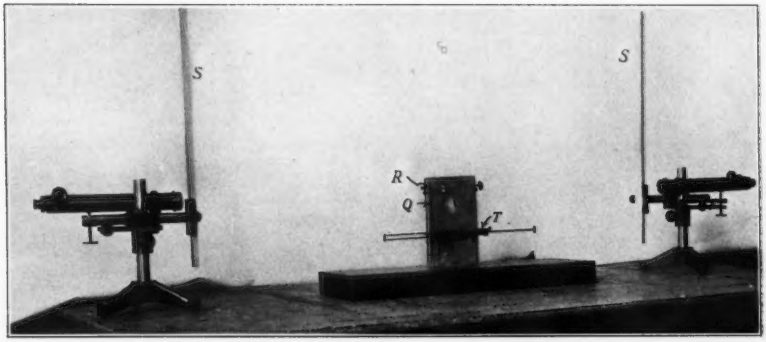


FIG. 2.—APPARATUS USED IN DETERMINING THE ELASTIC PROPERTIES OF BRICK.
R = ROCKER BEARING. S = SCALE.
Q = ROCKER LEVER. T = CLAMP.

then taken out separately and weighed, and thus the weight of each brick saturated with moisture was determined. Before weighing, the surplus water on the surface was removed by means of blotters. This gave the two weights necessary for determining the quantity of moisture absorbed.

Table No. 1 shows the range of absorption found, and is a good guide as to the absorption in common building brick. In this table it is seen that brick No. 63 has the lowest absorption, being only 147.4 gr., which is only 7% of its weight in the dry state; while the highest absorbed 490.7 gr., which is 14.19% of its dry weight. The average results from the 500 brick are also recorded in Table No. 1, and show a larger percentage of absorption than is generally allowed in specifications for common building brick. In specifications, in determining the percentage of absorption to be permitted, the weights of the natural brick and bricks filled with water are generally used. This method would tend to decrease the percentage of absorption, as recorded in Table No. 1, and bring it very close to that specified generally.

TABLE No. 1.—Absorption of Water in Brick.

Brick No.	Weight, in grams, before immersion.	Weight, in grams, after immersion.	Weight, in grams, of water absorbed.	Percentage of water absorbed.	Remarks.
42	1 993.0	2 193.6	200.6	10.07	
63	2 105.8	2 249.7	147.4	7.00	Very hard. Absorbed less water than any one of the 500 brick.
103	2 128.5	2 449.1	320.6	15.06	
109	2 015.8	2 506.5	490.7	24.34	Very soft. Absorbed more water than any one of the 500 brick.
173	1 995.5	2 222.8	227.3	11.39	
190	2 021.2	2 341.8	321.6	15.91	
217	1 997.0	2 315.7	318.7	15.95	
221	2 012.4	2 211.6	199.2	9.89	
225	2 087.0	2 369.4	282.4	13.53	
296	2 135.5	2 502.3	366.8	14.62	
365	2 129.1	2 462.6	333.5	15.66	
400	2 026.5	2 347.8	321.3	15.85	
Averages	2 053.9	2 347.7	294.2	14.19	
Average results from 500 specimens tested	2 030.52	2 351.39	320.87	15.80	

In constructing the oven, a hole, for an ash pit, was dug in the ground, the grate was placed on a level with the ground, and around this was built the oven. No bonding material was used in the casing

of the oven, the bricks being piled so as to break joints properly. In places where beams were required, wrought-iron pipes were used, and the brick placed on them. In order to prevent leakage of heat, as much as possible, the larger openings in the joints were filled with sand, and the roof was covered with a thick layer of the same substance.

Method and Apparatus Used in Determining the Elastic Properties.

All the brick used in determining the elastic properties were tested endwise. The initial load was 100 lbs., and when this load was applied, the initial reading was taken. A total load of 500 lbs. was then applied and a second reading taken. The load was then removed until a total of 100 lbs. was again obtained and a third reading taken. A pressure of 1 000 lbs. was applied and a fourth reading taken. The loading was again reduced to 100 lbs. and a fifth reading taken. This method of loading, unloading and reading was followed until it became evident that it would no longer be safe to allow the apparatus to remain attached to the brick. This part of the apparatus was then taken off, and the brick was tested for compression, endwise.

The foregoing method was followed with each of the bricks, and for each four curves were plotted as guides in determining its elastic properties. Two of the curves were plotted from readings taken from one edge, and the other two from the opposite edge of the brick. The plotting of the values on each side, computed from the differences of readings between the initial and the successive 100-lb. readings, gives the curve of permanent set. The two curves, one on each side, plotted from the values derived from the differences of readings between the initial loading and those of 500, 1 000, 1 500 lbs., etc., respectively, give the curve of distortion under the respective loadings. The average of the curves of permanent set for each brick was ascertained by taking the arithmetic mean—that is, the sum of the two values for the corresponding loading divided by two. The same method was followed in ascertaining the averages of the curves of distortion, thus making two average curves for each brick.

The apparatus used is shown in Fig. 2, Plate XXII, and consists essentially of two sets of parts, those not attached to the brick and those attached to the brick. In the former, for each side of the brick,

there is a standard containing a telescope with vertical and horizontal slow-motion screws, and a scale, S, graduated to centimeters. The latter consists of two rocker-levers, Q, rocker-bearings, R, with a mirror at one end of each, one of each for each side of the brick, and a clamp, T.

Where R and the lower end of Q would naturally bear against the brick, a small brass plate, in each place, was cemented to the brick, giving a brass bearing for these points. The details at R and the lower end of Q are shown in Fig. 1.

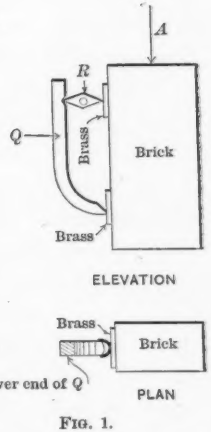


FIG. 1.

Now, as pressure is applied on the end of the brick, in the direction of the arrow, A, as shown in Fig. 1, the inside corner of R moves down, revolving about the edge in the groove of Q as a center. By this means, the mirror at the end of R moves through the same angle as R, thus giving different readings on the scale, S. The clamp, T, was used to hold Q and R in position.

When a total load of 100 lbs. was applied, the investigator looked through the telescope at the mirror and read the scale, in centimeters. On applying a heavier load on the brick, the mirror revolved, and a reading higher up the scale was obtained. The question then resolved itself into this form: How to find, from the differences of readings, the distortions under the respective loadings? Being able to find the differences of readings on the scale, then, by placing the scale, S, at a definite distance from the mirror, a constant was determined, which, when divided into the differences of scale readings, would give the distortions per unit of length for corresponding differences of loadings. This quantity is called the constant of the machine.

The determination of the constant for the apparatus is worked out as follows:

Length of $Q = 15$ cm.

Horizontal distance between bearings of $R = 0.44958$ cm.

Let the difference of readings (which means the difference between the initial reading and any other reading taken thereafter) be denoted by a; the distance from the mirror to the scale is denoted by z. After

a little computing, it was found that, with a constant of 6 000, a convenient value for z was obtained.

Let the total amount of distortion be denoted by x, then the distortion per unit of length is $= \frac{x}{15}$.

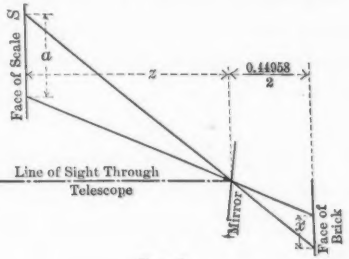


FIG. 2.

In the similar triangles of Fig. 2:

$$a : x = z : \frac{0.44958}{2}$$

$$\text{Therefore} \qquad x = \frac{\frac{0.44958\ a}{2}}{z} = \frac{a}{\frac{2\ z}{0.44958}}$$

$$\text{Therefore} \qquad x = \frac{\text{Difference of scale reading.}}{\frac{\text{2 distance of scale from mirror.}}{0.44958}}$$

$$\text{Hence} \qquad \frac{x}{15} = \frac{\text{Difference of scale reading.}}{\frac{15 \times \text{2 distance of scale from mirror.}}{0.44958}}$$

$$= \text{distortion per unit of length; and is applicable to any system of units.}$$

$$\text{Let} \qquad 6\,000 = \frac{15 \times \text{2 distance of scale from mirror.}}{0.44958}$$

$$\text{Therefore } z, \text{ distance of scale from mirror, } = \frac{6\,000 \times 0.44958}{2 \times 15}$$

$$= 89.916 \text{ cm.} = 34.4 \text{ ins.} = 2.95 \text{ ft.}$$

$$\text{Therefore} \qquad \frac{x}{15} = \frac{\text{Difference of scale reading.}}{6\,000}$$

Then, by placing the scale, S, 2.95 ft. from the mirror, the distortion per unit of length $\left(\frac{x}{15}\right)$ was obtained at a glance.

By this method the quantities used in plotting the elastic curves were obtained.

Compressive Tests of Brick.

This set was tested in the Riehlé, 400 000-lb. testing machine, and consists of brick on edge, on end, and flat, and 2-in. cubes, for natural, filled-with-water, and reheated brick. The brick tested on end were first tested for elastic properties, and, after the mirror micrometers had been removed, were tested for compression.

The photographs on Plates XXIV, XXV and XXVI show that in all cases the fractures are, in general, double-coned in outline, and that the apices of the cones meet in the middle. It will also be seen that the angle of the fracture with the bed-plane changes somewhat according to the way the bricks were tested, and varies more or less from 60 degrees.

In testing any material under compression it is claimed that a more accurate test is obtained by using cubes instead of rectangular blocks, the theory being that if tested on the flat a considerable percentage of the stress necessary for crushing is used up in friction, which takes place when the outside portion of the brick is pushed away to give room for the interior to crush, thus causing a greater stress than is necessary for crushing. In the case of testing on edge and on end it is advanced that bending, as in a column, is introduced to some extent. In the case of the cube there is no loss of stress due to friction on the bed-plate or head-block, and no tendency to bending, as in a column; and these, alone, are good reasons for selecting the cube as the ideal form of test piece.

By comparing the averages shown in Tables Nos. 2 to 8, it will be seen that in every case brick on the flat are the strongest, those on edge next to the strongest, those on end next to the weakest, while the cubes are the weakest. It will also be seen that in all cases reheated brick are the strongest, while brick filled with water are the weakest in the end and edge tests, and that natural brick are weakest in the flat and cube tests. Taking the natural cube as a standard test piece, the percentages of increase have been computed as follows:

Cube of brick; natural	1.0
Cube of brick; filled with water	2.2
Cube of brick; reheated	4.4
Natural brick; on end	15.2
Natural brick; on edge	27.1
Natural brick; flat	79.3
Brick filled with water; on end	4.1
Brick filled with water; on edge	22.0
Brick filled with water; flat	104.8
Reheated brick; on end	28.9
Reheated brick; on edge	49.3
Reheated brick; flat	121.7

TABLE No. 2.—Compressive Tests of Brick on End, for Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
97	1	14	8.53	8.66	8.89	3 763	2 092	3 063	30 102	17 391	24 699
98	2	25	8.91	8.77	8.70	1 234	3 193	2 169	9 952	15 945	17 348
99	3	26	8.54	8.91	8.89	2 742	1 603	2 717	22 536	13 120	21 990
100	4	53	8.70	8.65	8.77	2 826	2 281	2 509	22 698	18 393	20 229
101	5	73	8.65	8.72	8.84	2 952	1 977	3 446	23 893	16 004	28 000
102	6	91	8.70	8.53	8.77	2 733	3 153	1 908	22 035	24 436	15 383
103	7	94	8.72	8.58	8.96	1 663	2 539	2 918	13 357	20 074	23 711
104	8	100	8.84	8.84	8.51	2 602	2 553	2 343	21 063	20 825	18 962
105	9	104	8.15	8.86	8.67	2 101	2 289	1 737	16 874	19 028	13 630
106	10	171	8.53	8.72	8.72	3 339	2 523	2 905	28 802	21 527	22 879
107	11	176	8.72	8.91	8.30	2 606	1 829	3 836	21 498	15 059	31 051
108	12	185	8.22	8.54	8.58	2 976	1 802	4 896	23 808	14 865	39 169
Averages.....			8.60	8.72	8.72	2 628	2 320	2 871	20 986	18 889	23 088

TABLE No. 3.—Compressive Tests of Brick on Edge, for Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
109	13	194	19.30	17.45	18.35	2 137	2 880	3 521	8 146	10 530	13 427
110	14	283	17.96	18.93	18.00	3 099	2 226	4 278	11 711	8 348	13 984
111	15	285	18.18	18.34	18.21	3 021	2 284	2 550	11 610	8 635	9 404
112	16	412	18.32	18.28	18.35	3 199	3 165	2 722	12 096	11 969	10 462
113	17	416	17.96	18.68	18.14	2 878	2 594	3 438	10 614	9 728	13 215
114	18	426	18.39	18.72	18.28	2 055	2 445	3 253	7 771	9 245	12 098
115	19	430	18.61	18.14	17.87	3 050	2 567	2 502	11 628	10 507	9 617
116	20	459	18.03	18.72	18.28	2 621	2 291	3 605	9 829	8 590	13 405
117	21	465	18.03	18.00	18.39	2 949	2 707	3 931	11 150	10 150	14 864
118	22	467	17.77	18.75	18.39	1 897	2 720	4 043	7 290	8 840	15 540
119	23	468	17.75	18.00	18.46	3 913	4 104	2 986	14 674	15 007	11 479
120	24	479	18.21	18.57	19.19	3 164	2 623	3 087	14 459	9 919	11 867
Averages.....			18.21	18.38	18.24	2 832	2 717	3 326	10 748	10 122	12 447

TABLE No. 4.—Compressive Tests of Brick on Flat, for Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
121	25	128	31.23	30.99	31.37	4 183	5 893	5 256	8 758	12 707	11 662
122	26	160	31.35	31.35	29.77	4 310	4 783	5 783	9 294	10 049	12 651
123	27	161	31.35	31.23	31.11	5 463	4 923	5 831	12 122	10 462	12 572
124	28	181	31.48	31.35	31.11	2 791	4 527	5 307	6 104	8 771	11 775
125	29	189	31.33	31.36	31.36	3 539	3 359	3 541	7 851	6 925	7 745
126	30	279	32.87	31.23	31.74	2 665	5 613	3 862	5 650	11 402	8 327
127	31	346	31.23	31.48	31.62	4 525	4 583	4 419	9 898	10 024	9 804
128	32	411	31.48	31.10	32.12	3 941	5 303	3 975	8 745	11 269	9 069
129	33	431	31.97	31.95	30.98	3 623	4 005	4 482	8 039	8 510	10 084
130	34	432	30.35	31.73	31.86	3 999	3 623	5 792	8 625	8 039	12 670
131	35	442	31.73	31.36	31.24	4 272	5 039	6 520	9 078	11 021	14 059
132	36	487	31.11	31.21	31.48	4 625	3 097	4 500	9 973	6 774	9 563
Averages			31.45	31.36	31.31	3 995	4 562	4 939	8 678	9 663	10 832

TABLE No. 5.—Compressive Tests of Natural Brick.

Numbers.			Area of Section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.
97	109	121	8.53	19.30	31.23	3 763	2 137	4 183	30 102	8 146	8 758
98	110	122	8.91	17.96	31.35	1 234	3 099	4 310	9 952	11 711	9 294
99	111	123	8.54	18.18	31.35	2 742	3 021	5 463	22 536	11 610	12 122
100	112	124	8.70	18.32	31.48	2 826	3 199	2 791	22 698	12 096	6 104
101	113	125	8.65	17.96	31.33	2 952	2 878	3 539	23 893	10 614	7 851
102	114	126	8.70	18.39	32.87	2 733	2 055	2 665	22 035	7 771	5 650
103	115	127	8.72	18.61	31.23	1 663	3 050	4 525	13 357	11 628	9 898
104	116	128	8.84	18.03	31.48	2 602	2 621	3 941	21 063	9 829	8 745
105	117	129	8.15	18.02	31.97	2 101	2 949	3 623	16 874	11 150	8 039
106	118	130	8.53	17.77	30.35	3 339	1 897	3 999	23 802	7 290	8 625
107	119	131	8.72	17.75	31.73	2 606	3 913	4 272	21 498	14 674	9 078
108	120	132	8.22	18.21	31.11	2 976	3 164	4 625	23 808	12 459	9 973
Averages.....			8.60	18.21	31.45	2 628	2 832	3 995	20 986	10 748	8 678

TABLE No. 6.—Compressive Tests of Brick Filled with Water.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.
1	13	25	8.60	17.45	30.99	2 092	2 880	5 893	17 391	10 530	12 707
2	14	26	8.77	18.93	31.35	3 193	2 226	4 783	25 945	8 348	10 049
3	15	27	8.91	18.34	31.23	1 603	2 284	4 923	13 120	8 635	10 462
4	16	28	8.65	18.28	31.35	2 281	3 165	4 527	18 393	11 969	8 771
5	17	29	8.72	18.68	31.36	1 977	2 594	3 359	16 004	9 728	6 925
6	18	30	8.53	18.72	31.23	3 153	2 445	5 613	24 436	9 245	11 402
7	19	31	8.58	18.14	31.48	2 539	2 567	4 583	20 074	10 507	10 024
8	20	32	8.84	18.72	31.10	2 553	2 291	5 305	20 825	8 590	11 269
9	21	33	8.86	18.00	31.95	2 289	2 707	4 005	19 028	10 150	8 510
10	22	34	8.72	18.75	31.73	2 523	2 720	3 623	21 527	8 840	8 039
11	23	35	8.91	18.00	31.36	1 829	4 104	5 039	15 059	15 007	11 021
12	24	36	8.54	18.57	31.21	1 802	2 623	3 097	14 865	9 919	6 774
Averages.....			8.78	18.38	31.35	2 320	2 717	4 562	18 889	10 122	9 663

TABLE No. 7.—Compressive Tests of Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.
14	194	128	8.89	18.35	31.37	3 063	3 521	5 256	24 699	13 427	11 662
25	283	160	8.70	18.00	29.77	2 169	4 278	5 783	17 348	13 984	12 651
26	285	161	8.89	18.21	31.11	2 717	2 550	5 831	21 990	9 404	12 572
53	412	181	8.77	18.35	31.11	2 509	2 722	5 307	20 229	10 462	11 775
73	416	189	8.84	18.14	31.36	3 446	3 438	3 541	28 000	13 215	7 745
91	426	279	8.77	18.28	31.74	1 908	3 253	3 862	15 383	12 098	8 327
94	430	346	8.96	17.87	31.62	2 918	2 502	4 419	23 711	9 617	9 804
100	459	411	8.51	18.28	32.12	2 343	3 605	3 975	18 962	13 405	9 069
104	465	431	8.67	18.39	30.98	1 737	3 931	4 482	13 630	14 864	10 084
171	467	432	8.72	18.39	31.86	2 905	4 043	5 792	22 879	15 540	12 670
176	468	442	8.30	18.46	31.24	3 836	2 986	6 520	31 051	11 479	14 059
185	479	487	8.58	19.19	31.48	4 896	3 087	4 500	39 169	11 867	9 563
Averages.....			8.72	18.24	31.31	2 871	3 326	4 939	23 088	12 447	10 832

TABLE No. 8.—Compressive Tests of Two-Inch Cubes for Natural, Filled-with-Water, and Reheated Brick Cubes.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
*1	*13	95*a*	4.00	4.13	3.88	1 750	1 467	2 328	3 500	2 934	4 556
2	14	95*b*	4.13	4.00	4.13	3 985	3 500	2 179	7 970	7 000	4 358
3	15	152*a*	4.00	4.19	3.94	2 830	2 549	2 208	7 429	6 691	4 278
4	16	152*b*	4.13	4.06	3.94	2 864	2 628	2 292	5 728	5 256	4 584
5	17	228*a*	4.18	4.19	4.00	3 403	3 819	2 540	8 933	7 757	5 080
	18*a*	.....	.....	4.13	.....	.....	1 640	.....	.....	3 331	.....
6	18*b*	228*b*	4.19	4.06	4.06	1 715	1 844	2 709	4 502	3 688	5 518
7	19	347*a*	4.00	3.94	4.06	1 351	1 294	2 345	2 744	2 588	4 690
8	20	347*b*	4.06	4.13	4.06	1 106	1 094	2 841	2 247	2 188	5 682
9	21	421*a*	4.38	4.13	4.00	1 575	1 398	2 106	3 150	2 796	4 278
10	22	421*b*	4.32	4.13	3.94	2 609	2 838	2 142	6 849	5 753	4 284
11	23	447*a*	4.19	4.13	3.88	1 515	1 617	1 885	3 159	3 234	3 716
12	24	447*b*	4.00	4.13	3.94	2 035	3 234	2 338	4 070	8 489	4 530
Averages.....			4.13	4.10	3.99	2 228	2 273	2 326	5 023	4 873	4 638

* Nos. 1 and 13 were taken from the same brick, Nos. 2 and 14 from another brick, and the same order was followed for all the natural, and filled-with-water cubes, excepting in the cases of Nos. 6, 18*a* and 18*b*, in which cases three cubes were cut out of one brick.

A large hole was found in No. 18*a*, and though its test is recorded in this table, it is not included in the averages. No. 18*b* was cut from the same brick, and its test is included in the averages.

Taking the filled-with-water cube and the reheated cube as standards, the following percentages of increase have been computed: 2.1, 17.3, 100.7; 23.4, 43.0, 111.9 for end, edge, and flat, of filled-with-water and reheated brick, respectively. In Tables Nos. 2 to 8 the equivalent ultimate load per unit of height is given in pounds per square inch. This was obtained by multiplying the ultimate load, in pounds per square inch, by the height of the test piece. The object of ascertaining this was to see if some relation could be shown between the strength of a standard test piece (for example, a cube) and any other test piece, when the ratios of the areas to the heights are given.

In regard to the elastic properties, the averages of the results are shown by means of elastic curves, as seen in Figs. 3 and 4 and Plate XXIII. There are two methods of averaging these curves, the results of one being shown in Figs. 3 and 4, and the other on Plate XXIII, and

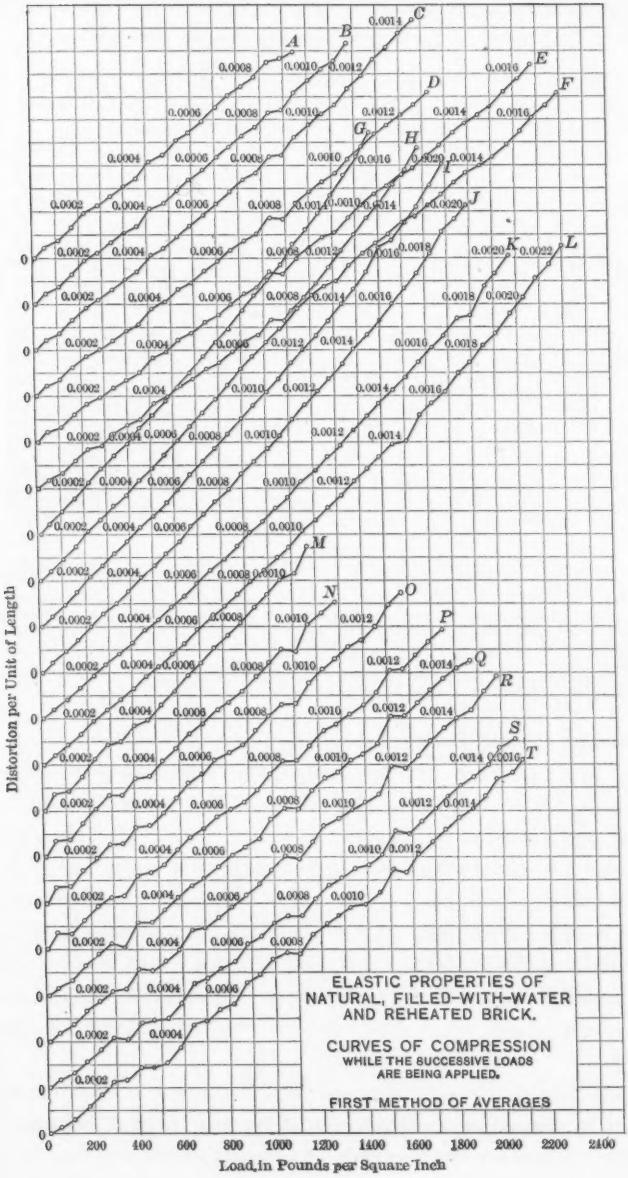
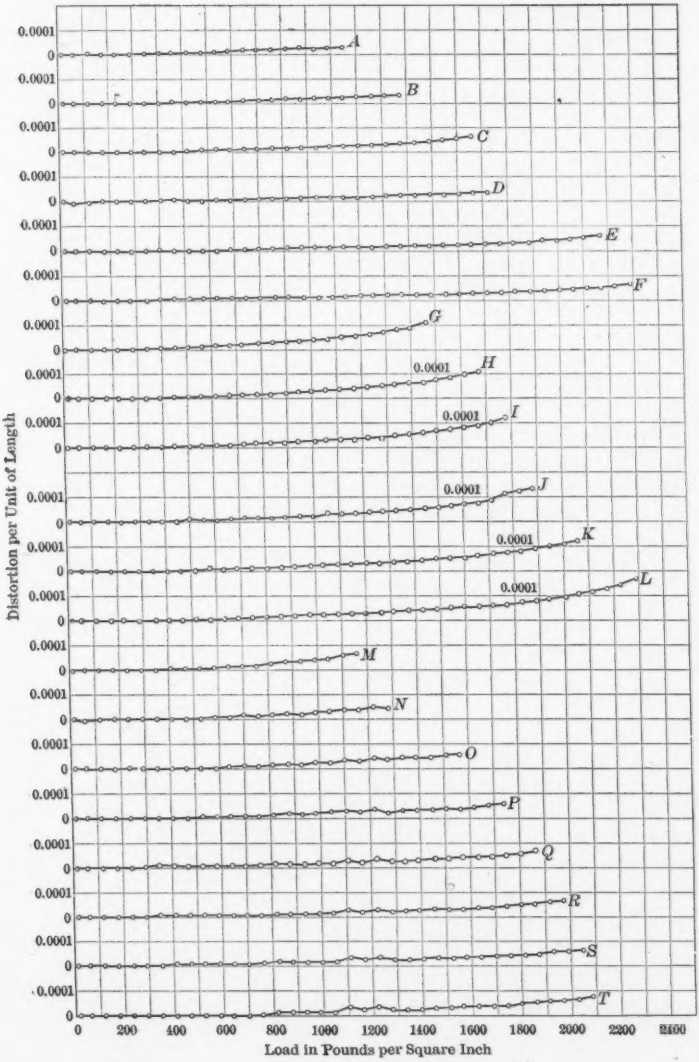

ELASTIC PROPERTIES OF NATURAL, FILLED-WITH-WATER AND REHEATED BRICK.
CURVES OF COMPRESSION
WHILE THE SUCCESSIVE LOADS ARE BEING APPLIED.
FIRST METHOD OF AVERAGES
Distortion per Unit of Length
Load, in Pounds per Square Inch
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
A B C D E F G H J K L M N O P Q R S T

FIG. 3.



ELASTIC PROPERTIES OF
NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

CURVES OF PERMANENT SET
AFTER THE SUCCESSIVE LOADS HAVE BEEN APPLIED AND THEN REMOVED

FIRST METHOD OF AVERAGES

FIG. 4.

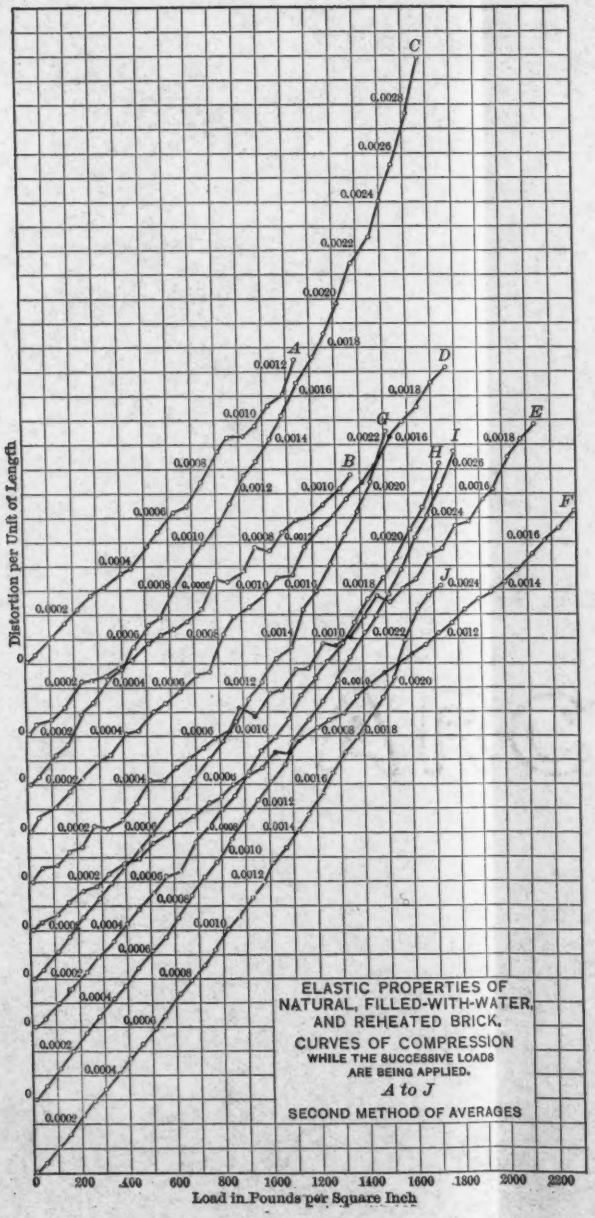
each method is divided into two sets, *viz.*, curves of compression and curves of permanent set, for natural, filled-with-water, and reheated brick. In the former set the curves are plotted from values obtained while the successive total loads of 100, 500, 1 000, 1 500 lbs., etc., were being applied, and in the latter case while the successive 100-lb. loadings were being applied. In these curves, the initial loading was taken as 100 lbs., which was 11 lbs. per square inch, more or less, instead of zero. The object in doing this was to be sure that the head-block was not removed from the test piece after it was once placed, thus securing the same bearing, which would not have always been the case had zero been used for the initial loading.

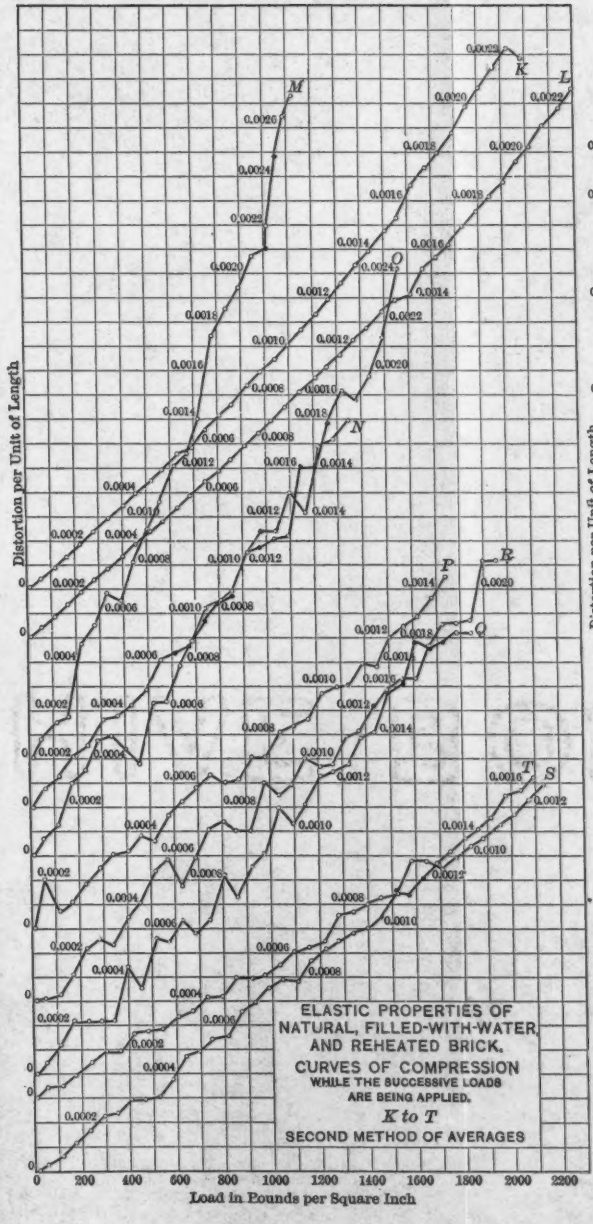
All the elastic curves, marked *M* to *T*, *G* to *L* and *A* to F, inclusive, are averages of natural, filled-with-water, and reheated brick, respectively. The method of averaging, in the first set, Figs. 3 and 4, taking the natural brick as an example, is as follows:

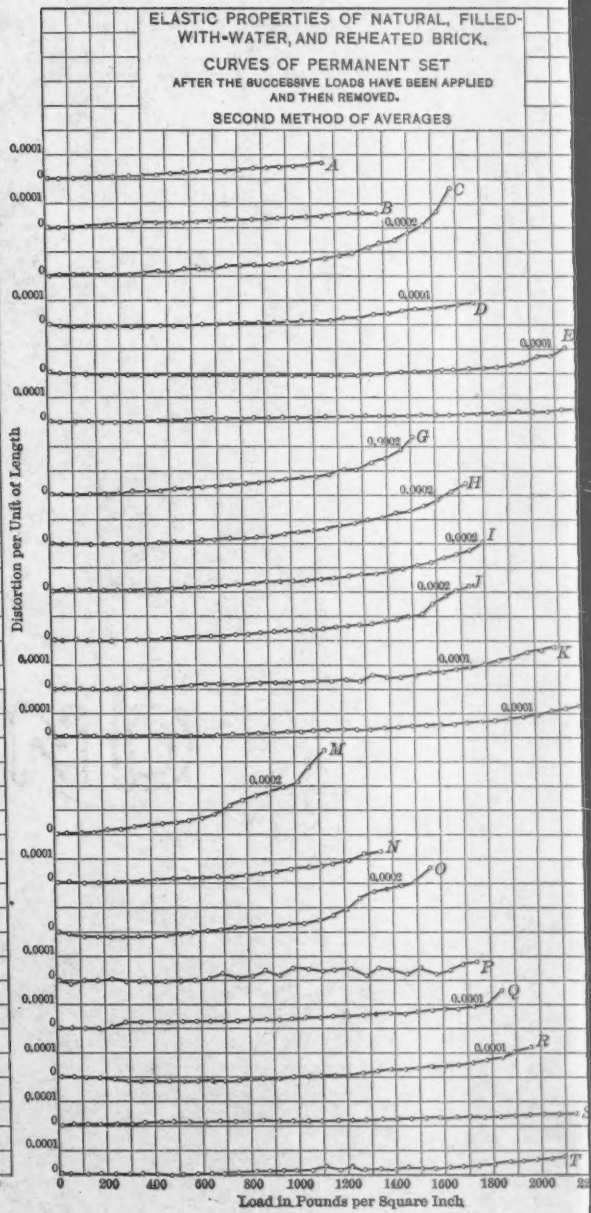
The total loadings reached by the several bricks, before the rocker bearing and rocker lever were removed, were as follows:

Brick No. 97, " " 101, " " 104, " " 106	18 000 lbs.	
" " 108	17 500	"
" " 107	17 000	"
" " 102	16 000	"
" " 99, " " 100	15 000	"
" " 103	14 500	"
" " 105	11 000	"
" " 98	10 000	"

Bricks Nos. 97, 101, 104 and 106 were averaged together up to 18 000 lbs. loading, making an average of four bricks, as shown in Curve *T*. Brick No. 108, together with Bricks Nos. 97, 101, 104 and 106, were averaged up to 17 500 lbs., making an average of five bricks for 17 500 lbs., as shown in Curve *S*. Brick No. 107, together with Bricks Nos. 97, 101, 104, 106 and 108, were averaged up to 17 000 lbs., making an average of six bricks, as shown in Curve *R*. Brick No. 102, together with Bricks Nos. 97, 101, 104, 106, 107 and 108, were averaged


ELASTIC PROPERTIES OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.
CURVES OF COMPRESSION
WHILE THE SUCCESSIVE LOADS ARE BEING APPLIED.
A to J
SECOND METHOD OF AVERAGES
Distortion per Unit of Length
Load in Pounds per Square Inch


ELASTIC PROPERTIES OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.
CURVES OF COMPRESSION
WHILE THE SUCCESSIVE LOADS ARE BEING APPLIED.
K to T
SECOND METHOD OF AVERAGES
Distortion per Unit of Length
Load in Pounds per Square Inch


ELASTIC PROPERTIES OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.
CURVES OF PERMANENT SET
AFTER THE SUCCESSIVE LOADS HAVE BEEN APPLIED AND THEN REMOVED.
SECOND METHOD OF AVERAGES
Distortion per Unit of Length
Load in Pounds per Square Inch

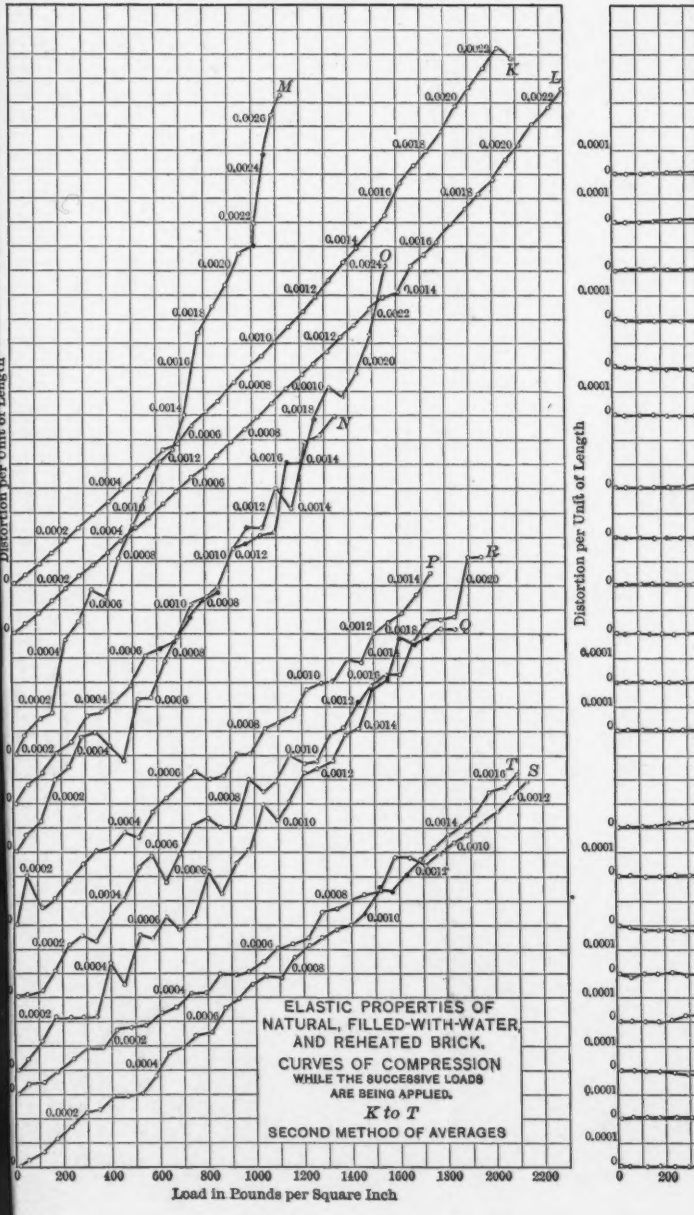
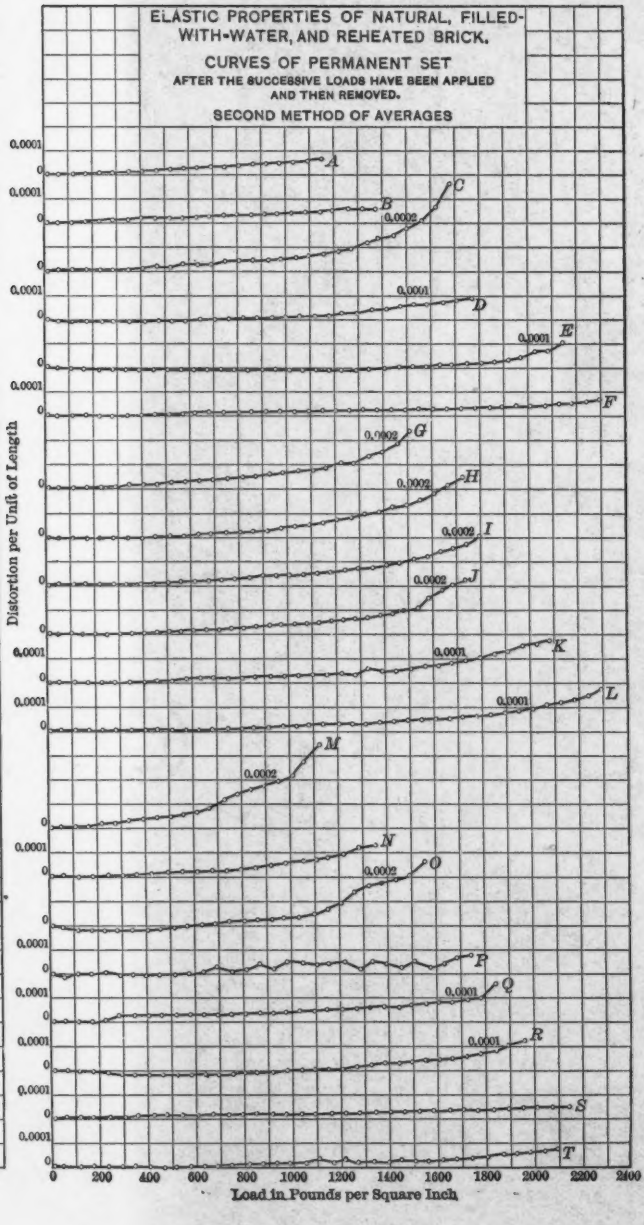

Distortion per Unit of Length
Load in Pounds per Square Inch
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
K
L
M
N
O
P
Q
R
S
T
ELASTIC PROPERTIES OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.
CURVES OF COMPRESSION
WHILE THE SUCCESSIVE LOADS ARE BEING APPLIED.
K to T
SECOND METHOD OF AVERAGES

PLATE XXIII.
PAPERS, AM. SOC. C. E.
MARCH, 1903.
TURRILL ON PHYSICAL PROPERTIES
OF BRICK.



together up to 16 000 lbs., making an average of seven bricks, as shown in Curve *Q*. This method of averaging was followed for the natural, reheated, and filled-with-water brick, each having its own independent averages.

In Figs. 3 and 4 the bricks included in the averages for the several curves are as follows:

Curve.	Numbers of Bricks.
A	Nos. 14, 53, 73, 94, 171, 176 and 185.
B	All bricks in *A*, and No. 26.
C	All bricks in *A*, and Nos. 26 and 100.
D	All bricks in *C*, and No. 104.
E	All bricks in *C*, and Nos. 91 and 104.
F	All bricks in *E*, and No. 25.
G	Nos. 2, 7, 8 and 10.
H	Nos. 2, 4, 7, 8 and 10.
I	Nos. 2, 4, 6, 7, 8, 9 and 10.
J	Nos. 2, 4, 6 and 7 to 11.
K	Nos. 2, 4 and 5 to 11.
L	Nos. 1 to 12.
M	Nos. 97, 101, 104 and 106.
N	Nos. 97, 101, 104, 106 and 108.
O	Nos. 97, 101, 104 and 106 to 108.
P	Nos. 97, 101, 102, 104, and 106 to 108.
Q	Nos. 97, 99 to 102, 104 and 106 to 108.
R	Nos. 97, 99 to 104 and 106 to 108.
S	Nos. 97 and 99 to 108.
T	Nos. 97 to 108.

In the second method, Plate XXIII, only those brick which were loaded up to the same point before removing the mirror micrometers are averaged in one curve. Those bricks (Nos. 97, 101, 104 and 106), carrying a loading of 18 000 lbs. before the removal of the mirror micrometers, are represented by Curve *T;* Curve *S* is the average of all bricks with a loading of 17 500 lbs., which is a single brick, No. 108; Curve *R* is made up of the average of all bricks with a load of 17 000 lbs., and consists of only one brick, No. 107; Curve *Q* is made up of all bricks with a load of 16 000 lbs., and is a single brick, No. 102; Curve *P* is made up of all bricks with a load of 15 000 lbs., and

consists of the average of two bricks, Nos. 99 and 100. This method of averaging was followed for the natural, reheated and filled-with-water brick, each having its own independent averages.

On Plate XXIII the bricks included in the averages for the several curves are as follows:

Curve.	Number of Bricks.
A	No. 25.
B	No. 91.
C	No. 104.
D	No. 100.
E	No. 26.
F	Nos. 73, 14, 176, 94, 185, 171 and 53.
G	Nos. 1, 3 and 12.
H	No. 5.
I	No. 11.
J	Nos. 6 and 9.
K	No. 4.
L	Nos. 2, 7, 8 and 10.
M	No. 98.
N	No. 105.
O	No. 103.
P	Nos. 99 and 100.
Q	No. 102.
R	No. 107.
S	No. 108.
T	Nos. 97, 101, 104 and 106.

The apparatus used in this test was very sensitive, so sensitive that even the vibration of the scale beam gave a slightly different reading. After taking the different readings, the differences of readings were computed. The values of the ordinates for the curves of compression were taken as the differences between the initial readings and the successive readings at the loadings of 500, 1 000, 1 500 lbs., etc., while the differences of readings for the curves for permanent set mean the differences between the initial readings and the successive 100-lb. readings, taken after the successive loads of 500, 1 000, 15 000 lbs., etc., had been applied.

By measuring an ordinate on a curve of permanent set and reading the value on the load line, one is able to tell at a glance between what

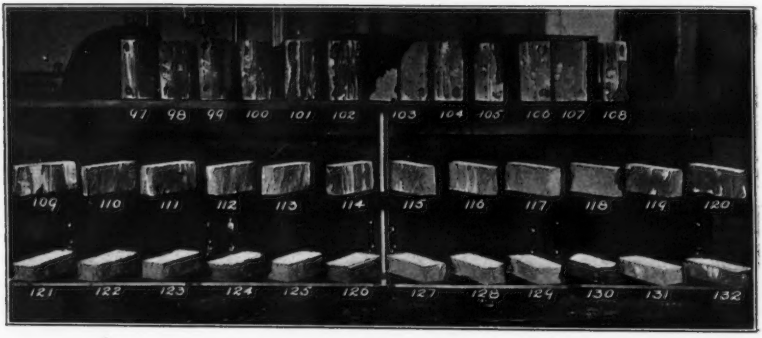


FIG. 1.—COMPRESSIVE TEST OF NATURAL BRICK.
NOS. 97 TO 108, COMPRESSED ON END.
NOS. 109 TO 120, COMPRESSED ON EDGE.
NOS. 121 TO 132, COMPRESSED ON FLAT.

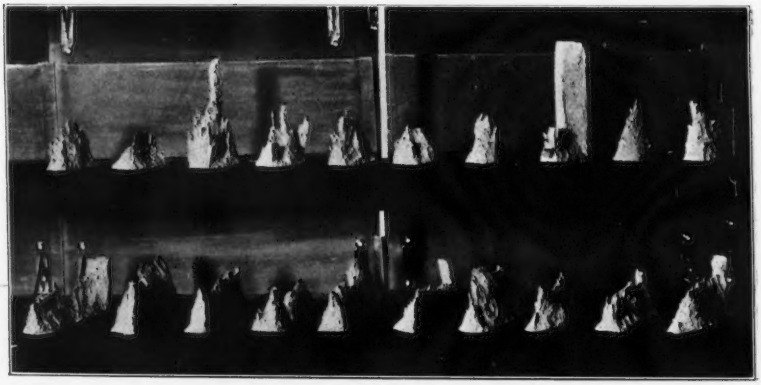


FIG. 2.—COMPRESSIVE TEST OF NATURAL BRICK.
ALL LOOSE PIECES HAVE BEEN REMOVED AFTER CRUSHING.
UPPER ROW, BRICK ON END.
LOWER ROW, BRICK ON EDGE.

two loadings, on the curve of compression, the 100-lb. reading was taken. For example, suppose there is a certain amount of distortion, measured by the length of an ordinate for a 100-lb. loading, located on the load line at 427 lbs. per square inch. This means that after a load of 427 lbs. per square inch had been applied for the curve of compression, a certain amount of permanent set, measured on that ordinate, took place under the following 100-lb. loading.

As a brick is made up of a granular substance, more or less irregularity in the elastic curves might be expected, and that they would be likely to be more irregular in natural brick, where the granular particles are dry and are thus unable to change their relative positions readily on account of friction, than in the case of brick filled with water, where the granular parts are wet and slippery, thus reducing friction to a minimum and allowing the particles to adjust themselves more freely under the respective loadings; or reheated brick, where the particles have become more solidified, and are now more of a solid mass and less granular, causing the brick to increase in stiffness and its particles to change their relative positions more uniformly. By examining the elastic curves, both for compression and permanent set, it will be seen that this statement is well substantiated; the curves for the natural brick being the most irregular, those for brick filled with water the most regular but the weakest in stiffness, while those for reheated brick show the greatest stiffness.

In testing any granular material, the theory is that these particles slide on one another, and change their relative positions under different loadings. Under a certain loading the particles occupy certain positions, but by applying a heavier loading they change their relative positions, causing, for example, the brick to shorten. Now, by releasing this loading, the particles adjust themselves to different positions. Upon applying a still heavier load it is found, that the brick is not distorted as much as under a less loading, showing that the particles, previous to this loading, had taken a firmer position, and that the irregularities of the curve are due to the greater or less compactness assumed by the particles from time to time.

Modulus of Elasticity.

The modulus of elasticity for compression was found for the initial loading and for every 500 lbs. of loading up to 10 000 lbs. for each

brick, thus giving twenty moduli for each brick. The average of these twenty moduli, which run very uniformly in nearly every brick, gave the average for the brick, as recorded in Table No. 9. The average for the twelve brick of each set is also recorded. The lowest modulus obtained in any brick was 500 000 lbs. per square inch, and the highest 2 500 000 lbs. per square inch. It will be seen from Table No. 9 that reheated brick have the highest moduli, while brick filled with water have the lowest.

TABLE No. 9.—MODULI FOR COMPRESSION, FOR NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

NUMBERS.			MODULI OF ELASTICITY, IN POUNDS PER SQUARE INCH.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
97	1	14	1 804 000	1 011 000	1 240 000
98	2	25	540 000	1 350 000	1 056 000
99	3	26	1 598 000	749 000	1 336 000
100	4	53	1 284 000	1 205 000	1 631 000
101	5	73	1 542 000	950 000	1 250 000
102	6	91	1 610 000	827 000	1 323 000
103	7	94	796 000	1 355 000	1 334 000
104	8	100	1 173 000	1 122 000	1 034 000
105	9	104	924 000	904 000	840 000
106	10	171	1 446 000	1 136 000	1 278 000
107	11	176	1 102 000	806 000	2 200 000
108	12	185	1 815 000	894 000	1 823 000
Averages.....			1 305 000	1 026 000	1 362 000

In computing the moduli, use was made of Hook's Law; that is, the distortion is proportional to the stress, within the elastic limit. Hence the moduli were obtained by dividing the stress by the corresponding distortion per unit of length.

The writer would have liked to determine also the moduli for shear, torsion, bending and tension, in addition to that for compression, if the distortions had been of sufficient magnitude to be measured.

TENSION TESTS OF BRICK.

In making the tension tests the Riehlé, 400 000-lb. testing machine was used, the apparatus consisting essentially of two clamps, one for each end of the brick, on a pivot bearing, as shown in Fig. 5.

The rod, *b*, was attached to the head-block of the testing machine and was allowed considerable lateral motion, so as to adjust itself to a direct pull on the brick during testing. The square bar, *a*, was



FIG. 1.—COMPRESSIVE TEST: BRICK FILLED WITH WATER.
COMPRESSION ON END, EDGE AND FLAT.

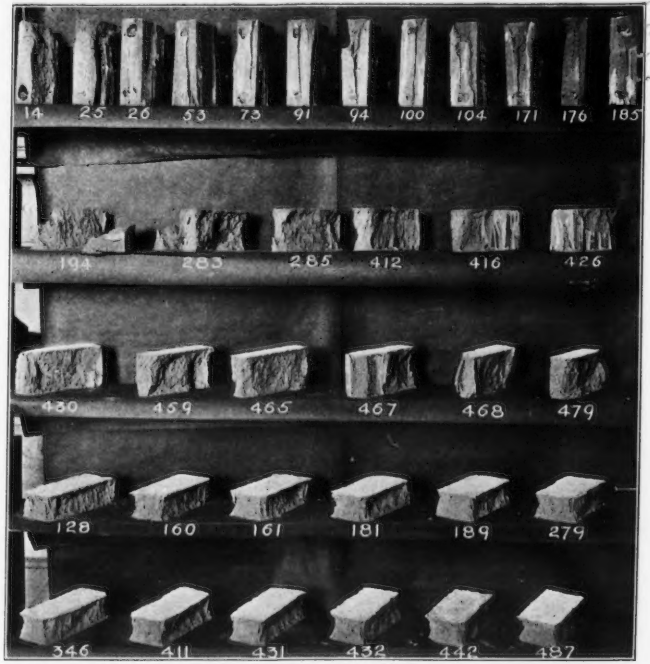
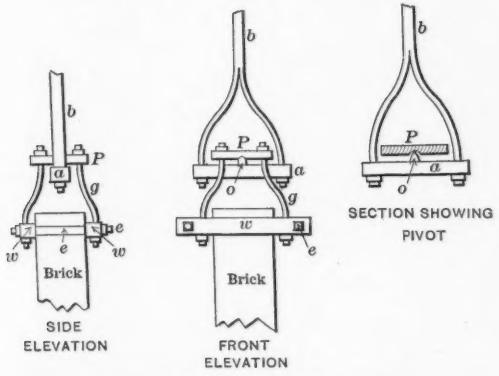


FIG. 2.—COMPRESSIVE TEST: REHEATED BRICK.
COMPRESSION ON END, EDGE AND FLAT.

bolted to the spread portion of the rod, *b*, and contained at its middle a pivot, *o*, upon which plate, *P*, and the lower part of the clamp had its bearing. The plate, *P*, rests upon *o* with considerable range of



CLAMPS USED IN TENSION TESTS.

FIG. 5.

movement, for the sake of direct pull during testing, as shown by the cone-shaped impression in Fig. 5. The bent rods, *g*, were not attached

TABLE No. 10.—TENSION TESTS OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

NUMBERS.			AREA OF SECTION, IN SQUARE INCHES.			ULTIMATE LOAD, IN POUNDS PER SQUARE INCH.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
1	25	96	8.89	8.65	8.51	269	201	411
2	26	133	8.53	8.84	8.58	292	189	266
3	27	142	8.77	8.84	8.51	205	219	182
4	28	155	8.72	8.67	8.58	123	218	163
5	29	191	9.11	8.96	8.84	149	112	169
6	30	215	9.08	8.82	8.89	127	204	149
7	31	231	8.82	8.84	8.44	263	242	402
8	32	422	8.67	8.77	8.55	111	186	216
9	33	428	8.65	8.96	8.60	282	234	159
10	34	459	8.89	8.65	8.70	328	278	161
11	35	460	8.65	8.39	8.63	156	238	157
12	36	491	9.23	8.65	8.70	107	188	268
Averages.....			8.83	8.75	8.63	201	209	225

rigidly to the plate, P, nor the jaws, w, but had sufficient play to allow the two jaws, w, to be separated so as to accommodate brick of varying thicknesses. With the brick in place it was fastened securely by means of the two bolts, e.

The results of the tension tests are recorded in Table No. 10. A photograph of the fractures is shown in Fig. 1, Plate XXVII. The results show that reheated brick will stand a higher tensile strain than those in either of the other conditions, and that brick filled with water is stronger than natural brick.

Engineers, in general, believe that the cause of failure of brickwork is due largely to tension, and as the tensile strength of brick is so low and the chances for stress under tension so pronounced, it looks as though this was one of its weak points.

Bending or Transverse Tests of Brick.

In this test the brick were tested flat, and had no plaster of Paris or ground surfaces for bearings, but rested directly upon knife-edges in an Olsen testing machine. The distance between the lower knife-edges was 7 ins. and the top knife-edge, to which the load was applied, was $3\frac{1}{2}$ ins. from either bearing.

The results tabulated in this test are the modulus of rupture or stress in the outer fiber, p, and the deflection at the center, D. In the former case the formula used was $p = \frac{3}{2}\frac{P\,l}{B\,h^3}$*, which is not strictly justified, but customary, in these cross-breaking tests of material having an elastic limit not easily determined. In the latter case, during the test, the deflection should have been measured, and the modulus, E, for bending, computed from the formula $D = \frac{1}{48} - \frac{P\,l^3}{E\,I}$†, which formula is true only within the elastic limit. The deflection was so small that the writer was unable to measure it, but, wishing to give some idea of the deflection in brick, he has computed the deflection from the foregoing formula, by using the breaking load and the modulus for compression. The true value of D would undoubtedly be smaller than the value obtained, as P, within the elastic limit, is somewhat smaller, and the modulus for bending considerably larger, than for compression.

* Johnson's "Materials of Construction."
† Church's "Mechanics of Engineering."



FIG. 1.—COMPRESSIVE TEST:
REHEATED BRICK AND BRICK FILLED WITH WATER.
ALL LOOSE PIECES HAVE BEEN REMOVED AFTER CRUSHING.
TWO UPPER ROWS: REHEATED BRICK.
THREE LOWER ROWS; BRICK FILLED WITH WATER.

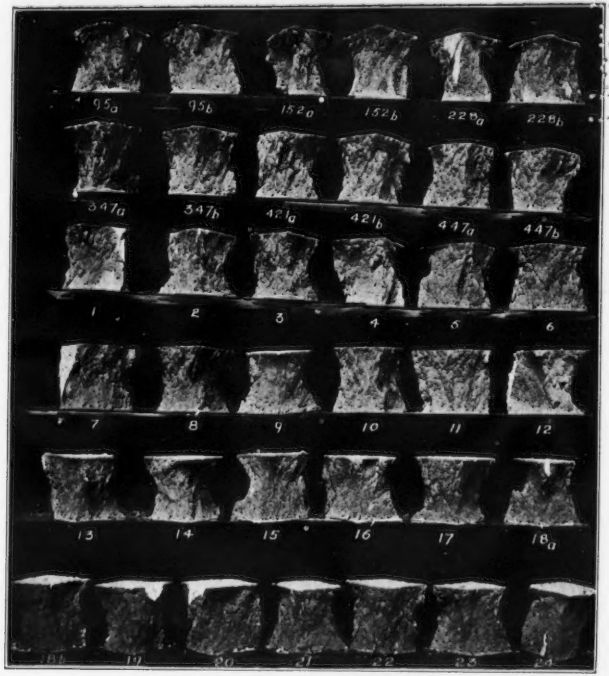


FIG. 2.—COMPRESSIVE TEST:
BRICK CUBES.
NOS. 95a TO 447b: REHEATED CUBES.
NOS. 1 TO 12: NATURAL CUBES.
NOS. 13 TO 24: CUBES FILLED WITH WATER.

In the foregoing formulas:

P = load at center;

l = length of brick;

b = width of brick;

h = height of brick;

I = moment of inertia of the section.

The theory has been advanced that the fibers above the neutral axis of a simple beam under any loading are in compression, while those below are in tension. A comparison of the results shown in Table No. 10 with those in Tables Nos. 2 to 8, for tension and compression, respectively, will show that bricks are weaker in the former tests than in the latter. From this, it would be inferred, naturally, that, as the vertical shear at the center is zero, the brick broke in tension. Upon looking at Table No. 11 it will be seen that the stress in the outer fiber is a little more than half the total load, and is larger than that caused by tension. The following question now arises. "The excess of stress in the outer fiber, over that of tension, is taken up in what forms of distortion?" This excess of stress, in all probability, is taken up mostly in compression, while a small portion of it, undoubtedly, is absorbed by horizontal shear.

TABLE No. 11.—TRANSVERSE OR BENDING TESTS OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

NUMBERS.			TOTAL LOAD AT CENTER, IN POUNDS.			STRESS IN OUTER FIBER UNDER BREAKING LOAD, IN POUNDS PER SQUARE INCH.			DEFLECTION AT THE CENTER UNDER BREAKING LOAD, IN INCHES.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
37	61	11	1 720	1 280	1 060	921	696	509	0.0026	0.0025	0.0013
38	62	89	1 060	1 440	1 800	537	736	971	0.0015	0.0026	0.0026
39	63	202	1 380	1 050	1 270	739	542	644	0.0021	0.0019	0.0017
40	64	260	920	1 370	2 000	459	733	1 097	0.0012	0.0026	0.0029
41	65	271	1 410	1 880	1 530	782	937	782	0.0023	0.0032	0.0021
42	66	370	1 470	1 500	1 510	772	809	821	0.0021	0.0029	0.0022
43	67	401	1 180	1 690	1 190	637	945	642	0.0018	0·0033	0.0017
44	68	438	2 000	1 720	1 380	1 125	1 019	730	0.0031	0.0038	0.0019
45	69	465	1 990	1 680	1 770	1 131	906	669	0.0032	0.0032	6.0015
46	70	472	1 990	1 530	1 980	1 101	775	1 077	0.0031	0.0027	0·0029
47	71	480	1 820	1 720	2 000	1 026	797	1 056	0.0029	0.0026	0.0027
48	72	488	1 990	1 030	1 960	1 126	495	991	0.0031	0.0017	0.0025
Averages.....			1 580	1 490	1 620	863	783	832	0.0024	0.0027	0.0022

Shearing Tests of Brick.

In these tests it will be noticed, upon referring to Table No. 12, that each brick was divided into halves, and that a record of the test of each half is shown. It will be seen that there is quite a difference in the strength of the two halves, showing that a single brick in itself is not perfectly homogeneous.

TABLE No. 12.—Shearing Tests of Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.								
						First half-brick.			Second half-brick.			Averages.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
1	25	9	8.58	8.96	8.89	583	138	349	636	179	562	610	158	455
2	26	58	8.89	8.23	8.65	371	535	497	367	705	514	369	620	505
3	27	129	8.82	8.58	8.58	380	186	262	330	385	271	355	286	266
4	28	212	8.77	8.00	8.65	381	800	509	285	625	512	333	712	510
5	29	236	8.77	8.79	8.51	274	210	544	310	319	670	292	265	607
6	30	261	8.65	8.89	8.84	453	685	543	763	353	430	608	519	486
7	31	265	8.84	8.77	8.63	279	319	513	353	506	618	316	412	565
8	32	450	8.34	8.65	8.44	528	309	461	507	116	409	518	213	435
9	33	469	8.44	8.84	8.65	585	236	370	476	411	403	530	324	386
10	34	475	7.93	8.46	8.79	908	355	165	542	693	198	725	524	182
11	35	477	8.13	8.27	8.63	492	293	554	223	235	292	358	264	423
12	36	495	8.46	8.77	8.89	212	253	484	449	380	579	330	316	526
Averages....			8.55	8.56	8.68	454	360	438	437	409	454	445	384	446

It is regretted that the moduli for shearing could not be obtained, for the reason that the deflections were so small that they could not be measured.

The fractures produced by these tests are shown in Fig. 2, Plate XXVII. The machine used was the Riehlé, 400 000-lb. testing machine, to which was attached the apparatus shown in Fig. 6.

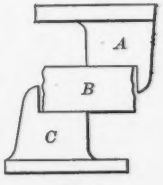


Fig. 6.

The upper shear is denoted by *A*, which was attached to the upper head-block, while the lower shear is marked *C*, and was attached to the bed-plate. The face of each shear is on the same vertical plane, which is the center of the machine. The half-brick to be tested is shown in place at *B*.



FIG. 1.—TENSION AND BENDING OF BRICK.
UPPER THREE ROWS IN TENSION.
LOWER THREE ROWS IN BENDING.



FIG. 2.—SHEAR AND TORSION OF BRICK.
UPPER THREE ROWS IN SHEAR.
LOWER THREE ROWS IN TORSION.

Torsional Tests of Brick.

As far as the writer knows, brick has never before been tested in this manner. Although, in actual brick construction, the stresses produced under this form of strain are very small and practically negligible, it was thought that it would be of interest to make such a test; thus completing a set of tests of all the forms of strain to which a brick can be subjected under ordinary engineering operations.

In conducting this test, the Thurston Autographic Testing Machine, sometimes spoken of as Thurston's Torsion Testing Machine, was used.*

The machine consists, essentially, of a pendulum, a drum, a curved guide by which a pencil arm is moved and traces upon the drum a permanent record, as shown in Figs. 9, 10 and 11. The test piece is held in place between the pendulum and the drum by two jaws.

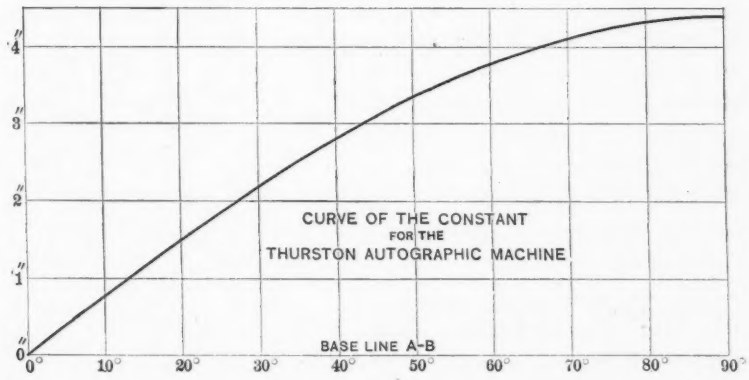


Fig. 7.

In carrying out the torsional tests the writer first standardized or found the constant of the machine, as follows: A piece of paper was first placed in the drum while it was unclamped on the shaft, with the upper end of the pencil rod in the hollow of the curved guide and the pencil on the drum, while it was turned through 180°, more or less, thus ruling the base line *A B*, as shown in Fig. 7, from which the ordinates are measured. As the pendulum was raised to a horizontal position, the pencil traced, on the paper in the drum, which was now clamped, the curve of the constant, as shown in Fig. 7. The pendulum

* A description and illustrations of the working parts of this machine may be found in Thurston's "Materials of Engineering," pp. 378 *et seq.* Reference may also be made to Carpenter's "Experimental Engineering," p. 96.

in the horizontal position was found to weigh 121 lbs. at the center of gravity of the weight, which was 4.16 ft. from the center of the head. The circumference of the drum was found to be 36 ins., which indicated that each inch on the base line was equivalent to an angular distance of 10° for both pencil and pendulum.

Sufficient data having been obtained, the constant of the machine was derived, as follows:

$P\,a = 121$ lbs. $\times$ 4.16 ft.

$= 503.36$ foot-pounds, the moment for the 90° position of the pendulum.

The length of the ordinate for the 90° position is 4.4 ins., and, as the constant of the machine is 503.36 foot-pounds, 4.4 ins. = 114.4 foot-pounds per inch of ordinate. The presence of some journal friction would necessitate this being accounted for in determining the final results. The pull at the center of the weight and 4.16 ft. from the center of the drum, to overcome the journal friction and hence pull the pendulum from its vertical position, was equivalent to $1\frac{7}{8}$ lbs. The constant for friction, or the frictional moment, is $1\frac{7}{8}$ lbs. $\times$ 4.16 ft. = 7.80 foot-pounds.

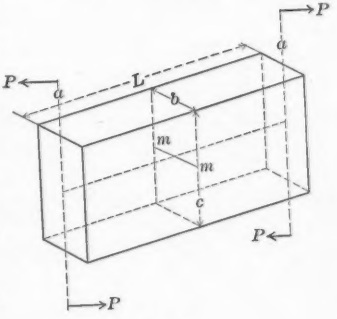


FIG. 8.

The test piece being rectangular in section, the theoretical results obtained by Grashof were taken. See Fig. 8.

Let L = length of brick actually subjected to torsion;

P_s = maximum shearing stress in the outer fiber (which will occur at the middle of the long side, at m) $= \frac{9}{2} \times \frac{P\,a}{b_2}\,c$;

α = angle of torsion, which (in π measure), for a length, L,

$$= \frac{9}{2} \times \frac{P\,a\,L}{E} \times b^2 + \frac{c^2}{b^3}\,c^3.$$

Of course, these formulas only apply if the elastic limit is not passed. To use them beyond this limit gives only approximate results, but, nevertheless, this is the best that can be done, under the circumstances.

TABLE No. 13.—Torsional Tests of Natural, Filled-with-Water, and Reheated Brick.

Shearing Stress in the Outer Fiber.

Numbers.			Natural brick.		Brick filled with water.		Reheated brick.	
Natural.	Filled with water.	Reheated.	Constant.	Stress under breaking load, in pounds per square inch.	Constant.	Stress under breaking load, in pounds per square inch.	Constant.	Stress under breaking load, in pounds per square inch.
37	61	13	0.229	414	0.219	359	0.223	559
38	62	143	0.225	526	0.229	503	0.233	470
39	63	203	0.219	532	0.229	462	0.223	324
40	64	206	0.225	402	0.221	258	0.242	659
41	65	211	0.251	750	0.221	261	0.163	325
42	66	219	0.247	817	0.225	368	0.217	422
43	67	388	0.253	626	0.231	370	0.169	410
44	68	402	0.249	724	0.275	916	0.229	603
45	69	455	0.233	552	0.273	759	0.213	863
46	70	456	0.251	658	0.231	598	0.213	420
47	71	489	0.244	517	0.264	734	0.213	410
48	72	493	0.238	790	0.239	632	0.219	381
Averages.....			0.239	609	0.238	518	0.213	487

TABLE No. 14.—Torsional Tests of Natural, Filled-with-Water, and Reheated Brick.

Modulus of Elasticity for Shearing.

Number.			Natural brick.		Brick filled with water.		Reheated brick.	
Natural.	Filled with water.	Reheated.	Constant.	Modulus, in pounds per square inch.	Constant.	Modulus, in pounds per square inch.	Constant.	Modulus, in pounds per square inch.
37	61	13	6.429	49 900	6.021	32 900	6.127	115 200
38	62	143	6.251	39 800	6.271	137 900	6.524	32 200
39	63	203	5.998	36 400	6.415	103 400	6.127	28 100
40	64	206	6.227	14 200	6.125	45 200	6.497	55 900
41	65	211	7.175	13 800	6.097	32 000	4.229	36 100
42	66	219	6.999	29 200	6.227	27 200	5.924	55 400
43	67	381	7.210	21 800	6.394	76 900	4.391	53 300
44	68	402	7.015	26 000	7.961	45 500	6.360	45 700
45	69	455	6.647	21 700	7.889	59 900	5.780	104 100
46	70	456	7.202	19 400	6.493	106 100	5.847	115 200
47	71	486	7.033	25 900	7.620	46 300	5.803	89 300
48	72	493	6.698	19 300	6.725	42 700	6.044	90 200
Averages.....			6.741	26 500	6.687	63 C00	5.810	68 400

Tables Nos. 13 and 14 show that there has been found by torsional tests, shearing stresses in the outer fiber, and the modulus of elasticity for shearing, in pounds per square inch, under the breaking load, the values in these tables being for the ordinates shown in dotted lines in Figs. 9, 10 and 11.

In arranging these two tables, both constants and stresses were given for each set of brick, thus enabling the reader to find the stresses for other ordinates of the curves of torsion, by means of the constant and measurement of ordinates and abscissas. The constant in the table of shearing stresses is equal to $\frac{9}{2} \times \frac{1}{b^2 c}$ which is a portion of the formula $p\sigma = \frac{9}{2} \times \frac{Pa}{b^2 c}$; while the constant in the table of moduli is equal to $\frac{9}{2} \times \frac{L}{\alpha_1} \times \frac{b^2 c^2}{b^3 c^3}$ (α_1 being the value of 10°, expressed in π measure), which is a portion of the formula

$$\alpha = \frac{9}{2} \times \frac{P a L}{E\sigma} \times \frac{b^2 c^2}{b^3 c^3} = \alpha_1$$

times the length, in inches, of the abscissa in question. The shearing stress for any ordinate, therefore, is the constant of the machine, expressed in inch-pounds, multiplied by the length of the ordinate, in inches, plus the frictional constant, in inch-pounds, which sum is $P a$, in the formula, and is multiplied by the constant in Table No. 13. The modulus for any ordinate is $P a$, divided by the corresponding abscissa, multiplied by the constant in Table No. 14.

The photograph, Fig. 2, Plate XXVI, shows the specimens which were submitted to torsional tests—natural brick in the upper row, reheated brick in the middle row, and brick filled with water in the bottom row. In all these three tests it will be seen that the corners gave way first, followed in most cases by a series of thin parallel curved planes. In no case did the failure take place in the central portion of the brick, nor, with such a brittle material, is it ever likely to take place there, unless the area of this portion is reduced considerably from what it is at the points where the test piece is held.

The distance the grips extend into the brick would have some bearing upon the number of parallel planes broken off and the distance of these planes from the corner. The farther the grip extends into the test piece, the more remote from the corner will the planes break off,

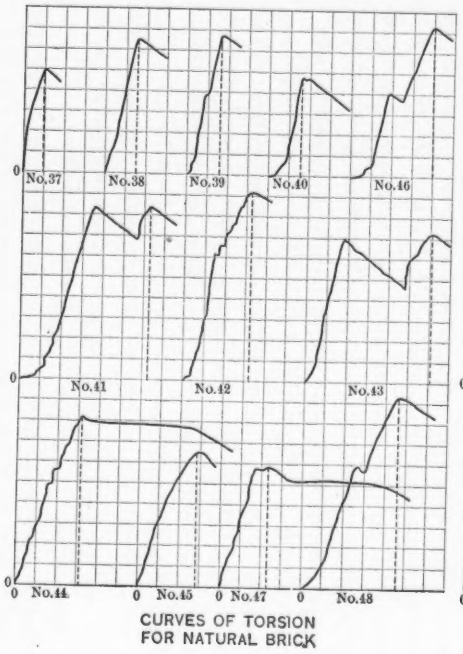


FIG. 9.

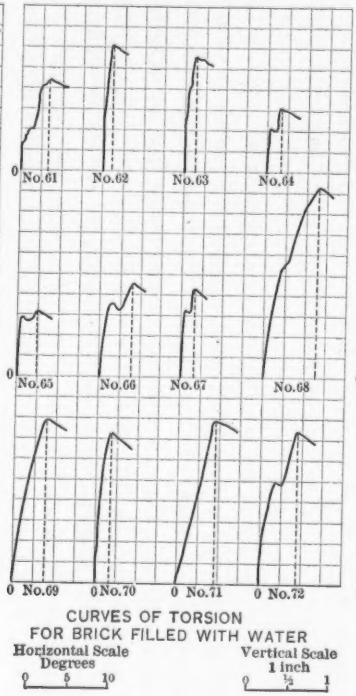


FIG. 10.

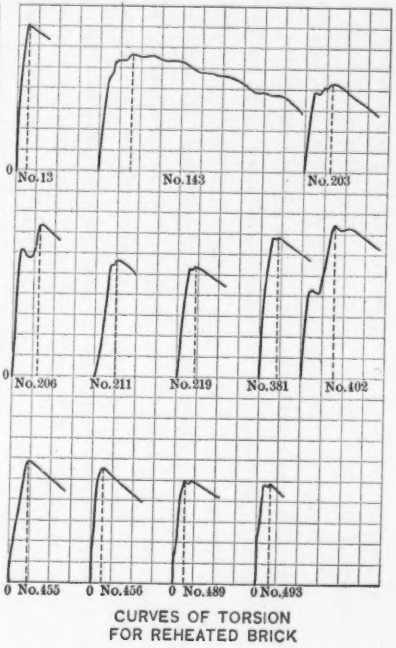


FIG. 11.

and the greater will be their number, while the distance between the parallel planes remains the same. The tendency in the brick is to break off at both of its corners at one end and turn around, with the center of each end as an axis, as in Brick No. 46, in Fig. 9. Sometimes the corners on ends diagonally opposite each other, or on the same edge, will fail first, leaving the brick between the grips, in a skew or square, respectively, as shown in Bricks Nos. 219 and 66, Figs. 10 and 11. In the foregoing tests the grip or jaw extended into the brick, which was held in place by wedges.

By examining the curves of torsion in Figs. 9, 10 and 11, it will be seen that there is more or less irregularity in the curves; indicating that the brick failed all at once or by degrees. The most regular curves are where they failed at once; the irregular curves are where they failed by degrees. The more the irregularity of the curve, the greater number of stages during failure, and, hence, the greater number of thin parallel planes.

By studying Tables Nos. 13 and 14, and the curves of torsion, it will be seen that the natural brick stood the highest in shear, and the reheated brick in moduli. The highest special brick in shear is No. 68, tested filled with water; while the highest in moduli is No. 62, which was also tested filled with water. It will be noticed that those bricks having curves with the longest ordinates are the highest bricks in shear, while those which have the shortest abscissas are the largest in moduli.

Conclusion.

In comparing the tables for the strength of the brick under different strains, one finds the following order of increase in strength, namely, tension, shear, torsion, bending, compression.

This order would naturally lead one to believe that the least important test was that of compression, and the most important that of tension, the others occupying places in the order given. But this does not follow, necessarily, for strains set up in certain directions are more marked than in others. For example, torsion would stand third in importance if rated in this way, but the writer believes this to be the least important test, because in brickwork torsional strains are less likely to be set up than any other form of strain.

The most important tests are tension and compression, as these strains are more likely to occur than any others, and, of these, tension

is the more important, as it is the weaker stress, and, when brickwork fails, bulging is brought out very prominently, and this produces tensional strains, and, to a less marked degree, bending and shear. Of the two remaining forms, bending is more important than shear, as strain along this line is more likely to occur than in shear, although shear shows the weaker stress.

As to the best kind of brick to use, the tables and the curves of distortion show results decidedly in favor of reheated brick; but, taking into account the expense of preparing reheated brick and the loss of 12% of them, it would be cheaper to use enough extra natural brick to make up the excess of strength found in reheated brick, unless the reheating has been done in a conflagration. Natural brick and brick filled with water show about the same results, so that, in general, the water does not impair the strength of the brick.

In the compression test, the brick on flat are the strongest, while the brick cubes are the weakest, and the brick on end are weaker than those on edge. In this test the pieces are 2, 4 and 8 ins. in height, from which the strength for a square inch for the respective heights can be computed. The question comes up: What would be the strength of each of these specimens if it were only 1 in. high? The writer has assumed that the specimens would increase in strength per square inch as many times as the specimen is inches in height, and has, as a result, the figures given in the columns headed, "Equivalent ultimate load per unit of height, in pounds per square inch." The results show that this assumption is wrong, and that some other ratio of the height exists. What this is can be found more satisfactorily by tests than by assumptions.

By looking at the shearing and torsional tests, Tables Nos. 12 and 13, respectively, it is seen that those in Table No. 12 are for direct shear, and those in Table No. 13 are for shear in the outer fiber, caused by torsional strain. In the case of reheated brick, the stresses are about the same in both tables, those in No. 13 being a little larger, while the greatest difference is in the natural brick, those in Table No. 13 being about one and one-half times those found in Table No. 12. In these two tables the important test is that of direct shear.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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A SMALL ROCK-FILL DAM.

By H. de B. Parsons, M. Am. Soc. C. E.

To be Presented May 6th, 1903.

The rock-fill dam described in this paper was designed by the writer for George Crocker, Esq., to impound a gravity water supply for his estate at Darlington, near Ramseys, New Jersey.

The site selected was at the head of a ravine where the hills widened out, forming a natural bed for a lake. The site was about 250 ft. above the farm buildings in the valley of the Ramapo River, and about 65 ft. above the point selected for the new residence.

The small brook running down the ravine had a probable summer average flow of from 9 to 10 cu. ft. per second. During extreme freshets, this flow was increased rapidly, probably to sixty or seventy fold, as, owing to the rocky formation of the hills in this locality, the run-off and rainfall are nearly equal.

A dam height of 20 ft. was decided upon as being sufficient to impound about 11½ acres of lake surface. The length along the crest was 235 ft.

Rock outcropped on the east side of the brook, but disappeared on the west side. Test pits dug on the latter side showed the covering to consist of: Gravel and soil, 1 ft. 6 ins.; mixed sand, gravel and

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

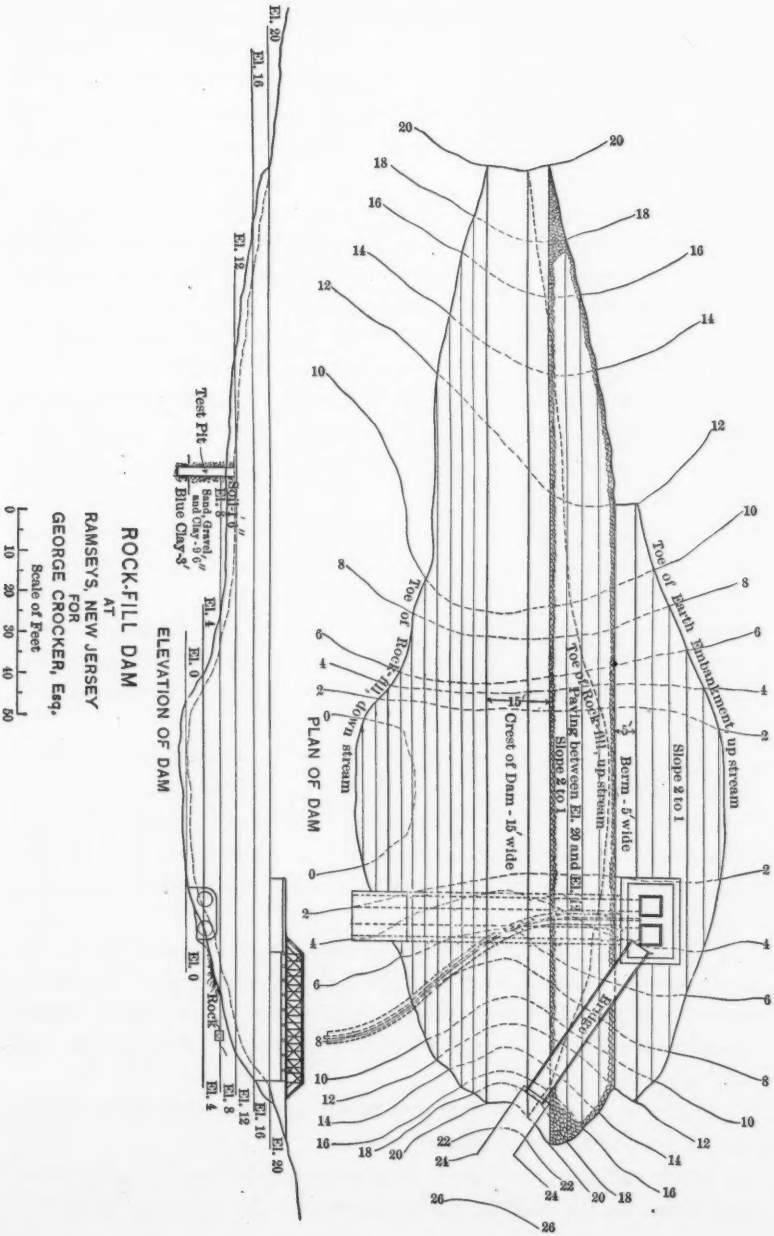

El. 20
El. 16
El. 12
Test Pits
Soil 1'
Sand, Gravel 6'
Sand Clay - 9'
Blue Clay - 3'
El. 8
El. 4
El. 0
Rock
ELEVATION OF DAM
Toe of Rock-fill
Down stream
PLAN OF DAM
Crest of Dam - 15' wide
Toe of Rock-fill up-stream
Paving between El. 20 and El. 8
Slope 2 to 1
Berm - 5' wide
Toe of Earth Embankment up stream
Slope 2 to 1
Bridge
ROCK-FILL DAM
AT
RAMSEYS, NEW JERSEY
FOR
GEORGE CROCKER, Esq.
Scale of Feet
0 10 20 30 40 50

FIG. 1.

clay, 9 ft. 6 ins., and blue clay beneath. The outcropping rock was found to be seamy and somewhat broken. The approach to the site, by road, was difficult, due to the steep incline. The problem, therefore, was the design of some form of dam which would be easy to erect and would require the least amount of falsework or contractor's apparatus.

Under the foregoing conditions it was decided that a rock-fill dam, backed with earth on the water side, was the most expedient. Furthermore, the cost of such a dam was estimated to be less than one-third of the cost of a masonry dam of equal size.

The general plan and down-stream elevation are shown in Fig. 1, the cross-section in Fig. 2, and the gate-house in Fig. 3

The rock on the east bank was blasted out, so as to provide a foundation for the gate-house, and the surface rock was prepared to receive the rock-fill. All seams and cracks in the rock were pointed carefully with Portland cement.

The earth and soil, for a depth of about 18 ins., was removed from the site of the dam between the up- and down-stream toes. A trench, about 30 ins. deep, was then dug along the up-stream toe, and a double row of sheet-piles, with lapped joints, was driven. These piles were 3 ins. thick, and were driven until rock was reached or the end entered the blue-clay stratum. In no place did they exceed 14 ft. in length.

The gate-house and blow-off pipes were then constructed. The gate-house was built of rubble masonry, laid in Portland cement mortar consisting of 1 unit by measure of cement to $2\frac{1}{2}$ units of sand. The grooves for the gates and screens were six-hammered. The top was finished with a cut-stone coping, filled flush at the center with concrete.

The blow-off pipes were 36 ins. in diameter, and were of steel, $\frac{1}{4}$ in. in thickness, stiffened every 10 ft. by 3 x 3-in. angles, which also acted as water stops. The sheets were single-riveted and caulked. These pipes were bedded in concrete, which was tamped closely under and around them.

Ridges were left in the concrete to act as water stops and to hold the rock fill and earth in place.

When sufficient work had been accomplished on the gate-house and blow-offs, the rock fill was commenced. By thus regulating the

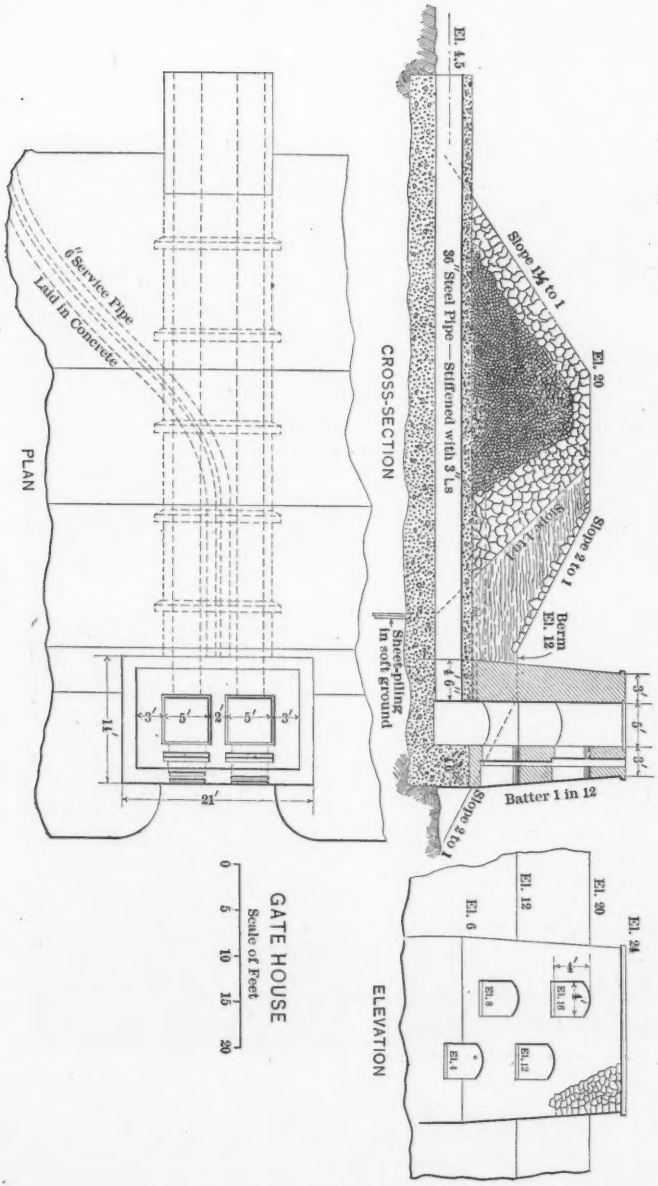

PLAN
6" Service Pipe Laid in Concrete
14'
21'
5'
2'
CROSS-SECTION
El. 4.5
36" Steel Pipe — Stiffened with 8" L's
Slope 1½ to 1
El. 20
Slope 2 to 1
Slope 2 to 1
Berm El. 12
4' 6"
Sheet-piling in soft ground
3'
6'
3'
Batter 1 in 12
Slope 2 to 1
ELEVATION
El. 20
El. 12
El. 6
El. 24
El. 18
El. 8
El. 12
El. 4
4'
GATE HOUSE
Scale of Feet
0 5 10 15 20

FIG. 2.

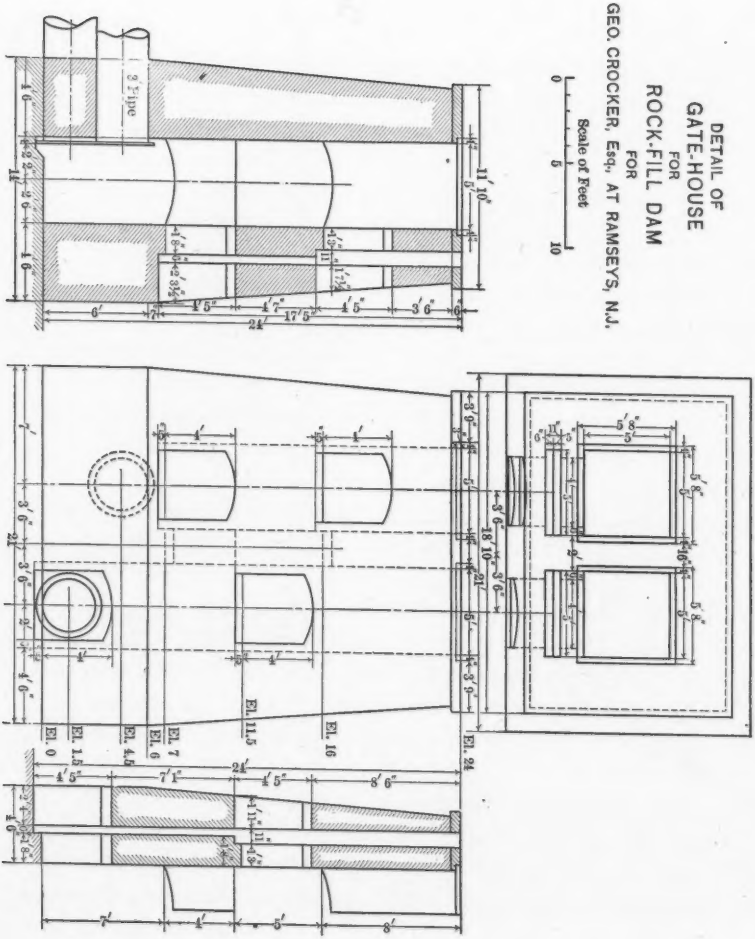

DETAIL OF
GATE-HOUSE
FOR
ROCK-FILL DAM
FOR
GEO. CROCKER, Esq., AT RAMSEYS, N.J.
Scale of Feet
0
5
10
3' Pipe
El. 0
El. 1.5
El. 4.5
El. 6
El. 7
El. 11.5
El. 16
El. 24

Fig. 3.



FIG. 1.—PROGRESS OF WORK, JULY 1ST, 1902.



FIG. 2.—PROGRESS OF WORK, AUGUST 1ST, 1902.

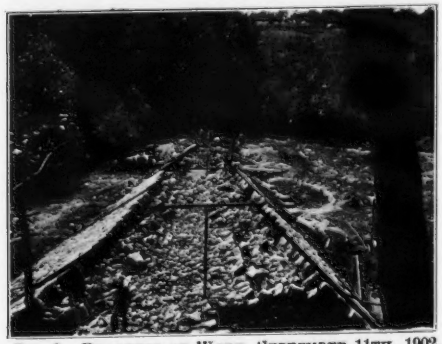


FIG. 3.—PROGRESS OF WORK, SEPTEMBER 11TH, 1902.



FIG. 4.—PROJECTING ENDS OF BLOW-OFF PIPES.

work, the brook was allowed to follow its natural course until the rock fill began to dam it up, when the water was passed through the lower of the blow-off pipes. The work could thus be carried on from beginning to end in a dry state and without the use of coffer-dams or other falsework.

The rock fill was made from stone, blasted out of the hillside, loaded on wagons and simply dumped on the work. Care was taken to build up the wall in horizontal layers, and to use a sufficient quantity of small stones and spawls to fill the voids as full as possible. The stone carts were driven over the work as it progressed, in order to help jar and pack the stones. The stones were all cleaned carefully before being put into the wall; and, in shape, were rough and jagged, all smooth stones being rejected.

The best-shaped stones were reserved for hand placing on the two faces. On the down-stream face, the hand packing was about 5 ft. thick, and on the up-stream face from 5 ft. at the crest to 10 ft. at the toe. This hand packing resembled dry rubble masonry, and was carried up a little in advance of the center filling. Its object on the up-stream face was to help make the dam water-tight by offering narrow and broken joints, which would retain the matter carried in by leakage. On the down-stream face, the object was to permit the dam to overflow without material injury. No spillway was provided in the crest, because the dam was intended to be used as a driveway during the summer season. It is only at rare intervals that the dam is expected to overflow, and the long crest will allow ample way for the water, which will not be more than a few inches in depth on the crest, even at periods of worst flood. Such floods last only a short time. Should injury be done by ice or overflow, the damage can be easily repaired.

The earth fill consisted almost entirely of clay, which, luckily, was more abundant than had at first been anticipated. It was carried up in horizontal layers, about 6 ins. in thickness, and each layer was well watered and rolled with a grooved two-horse roller. The water side was paved above the berm with flat stones, laid so as to have an average depth of 12 ins. This was done as a protection against ice.

At the east end of the crest, a rubble stone abutment was built, and a light, steel-truss bridge extended to the top of the gate-house.

The water service pipe was of lap-welded, wrought iron, 6 ins. in diameter, with the lengths joined by heavy flanges, having faces turned true, and bedded in the concrete mass with the blow-offs.

The work was commenced on May 21st, and completed on November 8th, 1902. When finished, the dam was practically water-tight. There was a slight leak at the lower of the blow-off pipes, but this diminished in volume rapidly, and ceased in about thirty days.

Fig. 1, Plate XXVIII, shows the progress of the work on July 1st. The cut-off trench for the sheet-piling is seen on the left, and the blow-off pipes in the back-ground.

Fig. 2, Plate XXVIII, shows the progress of the work on August 1st. The sheet-piling is seen clearly on the right, and the rock fill in the foreground.

Fig. 3, Plate XXVIII, shows the progress of the work on September 11th. The construction of the dam is seen in this photograph. The hand-placed material on both up- and down-stream faces, with the loose rock fill in the center, is easily distinguishable.

Fig. 4, Plate XXVIII, shows the down-stream ends of the blow-off pipes embedded in the concrete and projecting through the dam. The photograph also shows the character of the hand-placed work.

Fig. 1, Plate XXIX, shows the progress of the work on October 21st. The commencement of the earth embankment will be noticed on the right.

Fig. 2, Plate XXIX, shows the gate-house structure on October 21st.

Figs. 3 and 4, Plate XXIX, show the completed structure, with the pond about half full.

The dimensions of the dam are:

Length on crest	235 ft.
Height at center	20 "
Width of crest, total	15 "
" " " masonry	10 "
" " " earth	5 "
Slope of masonry, up-stream face	1 on 1
" " " down-stream face	1 on 1½
" " earth embankment	1 on 2

The contract price was $8 700.

The quantities, and a close estimate of the unit prices, are given in Table No. 1. These unit prices include all the contractor's expenses, but not his profit, as the work appeared to cost all of the contract price.



FIG. 1.—PROGRESS OF WORK, OCTOBER 21ST, 1902.



FIG. 2.—THE GATE-HOUSE ON OCTOBER 21ST, 1902.



FIG. 3.—THE COMPLETED DAM.



FIG. 4.—THE COMPLETED DAM.

TABLE No. 1.

Item.	Quantity.	Unit Price.
Earth excavation	794 cu yds.	$0.30
Earth embankment, including rolling	12 570 " "	0.43
Rock excavation	210 " "	1.60
Rock fill, core filling	1 642 " "	0.45
Rock fill, hand-packed	1 353 " "	0.95
Timber, sheet-piling	13 200 ft. B. M.	54.00
Timber, gates, bridge floor, etc.	1 200 " "	80.00
Concrete	120 cu. yds.	7.80
Paving	142 " "	1.70
Rubble masonry	157 " "	8.10
Fine-hammered facing	136 sq. ft.	0.80
Steel bridge	3 000 lbs.	0.10
Blow offs and service pipes	16 150 "	0.10
Gate-valves, two 36-in. and one 6-in.	3	220.00
Hand-power winch	1	40.00

The contractor was Mr. Watson E. De Baun, of Tuxedo, New York, to whom, and to Mr. James White, his foreman in charge, credit is due for the faithful way in which they carried out the intent of the specifications. The writer also acknowledges his thanks to William A. Cattell, M. Am. Soc. C. E., for some suggestions, and to H. B. Atkins, Assoc. M. Am. Soc. C. E., and Mr. John W. Doty for their supervision of the construction.

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DEFLECTIONS OF BEAMS WITH VARIABLE MOMENTS OF INERTIA.

By C. W. Hudson, M. Am. Soc. C. E.

To be Presented May 6th, 1903.

The determination of the deflections for the special types of open-webbed, elastic frameworks often met with in the practice of the bridge engineer has received much attention, and very exact solutions are made for these problems by both graphical and analytical methods.

The determination of the deflections for solid-webbed girders, which is of equal theoretical interest and often of great practical importance, however, has been confined chiefly to girders with a constant moment of inertia, and such determinations have usually been made by means of the equation of the elastic curve. It is the purpose of this paper to give a more general method for determining the deflections of solid-webbed girders under flexure, and to illustrate its application to the forms of girders most frequently met in practical bridge construction. The plate-girder drawbridge, owing to its frequent use, is one of the most important structures with which the bridge engineer has to deal. Application of the general formula to this case has been made, with the object of giving a simple method of making a better design for the girders and end-lifting machinery for these bridges.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The writer believes that the determination of the deflection of girders with solid webs is effected best by means of the method of work. The general formula is derived, it will be noticed, in a manner very similar to that commonly used in obtaining the general formula for the deflections of articulate structures.

Let us suppose a beam of any shape in equilibrium under the action of a given loading, and that the following derivation is made under the usual conditions imposed in the development of the fundamental formulas for flexure, and under the supposition that, where the forces producing bending have components in the direction of the length of the beam, the effect of such components in producing distortion may be neglected.

Let M = the bending moment at any section of the beam due to the given loading;

S = the unit stress due to flexure on any fiber of the cross-section, the fiber being distant y from the neutral axis, and

I = the moment of inertia of the cross-section for which the other quantities are taken.

Then, from the fundamental relation for flexure, we have $S = \frac{My}{I}$.

Under the action of flexure, the fibers on one side of the neutral axis of a beam are lengthened, and on the other side they are shortened.

Let dx (an infinitesimal) be a portion of the length of the beam, and λ be the change in length of any fiber distant y from the neutral axis, due to flexure.

From Hooke's Law, we have $\lambda = \frac{SL}{E}$, in general, and for a fiber of a length dx, $\lambda = \frac{S\,dx}{E}$, in which E is the coefficient of elasticity of the material.

Since $S = \frac{My}{I}$,

$$\lambda = \frac{My}{EI}\,dx.$$

Now, simultaneously with the given loading, suppose a force of unity to be applied to the beam at any point in any desired direction. Let m be the bending moment at any section of the beam thereby produced. The stress on any fiber (the same fiber for which λ is taken) of

any section due to the assumed load of unity $= \frac{m\,y}{I}$, and the work done by this stress, assuming it to be gradually produced, acting through the distance λ, is equal to $\frac{m\,y}{2\,I} \times \lambda = \frac{M\,y}{2\,I} \times \frac{m\,y}{E\,I} dx = \frac{M\,m\,y^2\,dx}{2\,E\,I^2}$.

Letting $\int d\,A$ represent the area of the entire cross-section, the work done on an infinitesimal portion of the length of the beam $= \frac{M\,m}{2\,E\,I^2}\left(\int y^2\,d\,A\right) dx$, and since $\int y^2\,d\,A = I$, this work $= \frac{M\,m\,d\,x}{2\,E\,I}$, and for the internal work throughout the length of the beam due to flexure we have:

$$W = \int_o^l \frac{M\,m\,d\,x}{2\,E\,I} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Again, let Δ be the deflection, due to the given loading, of the point at which the force of unity is applied, measured along the line of action of the force unity, then the work done by the force of unity gradually applied is:

$$W = \frac{1}{2} \times \Delta = \frac{\Delta}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Making the total work of the internal stresses due to flexure (1) equal to the total work of the external forces (2), we have:

$$\frac{\Delta}{2} = \int_o^l \frac{M\,m\,d\,x}{2\,E\,I}$$

$$\Delta = \int_o^l \frac{M\,m\,d\,x}{E\,I}^* \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

which is the general value for the deflection of any point in a beam.

As an illustration of the general application of this formula, suppose we find the horizontal deflection of the upper corner of a simple I-beam span, loaded at the center with the weight P. Fig. 1 will make the problem more clear.

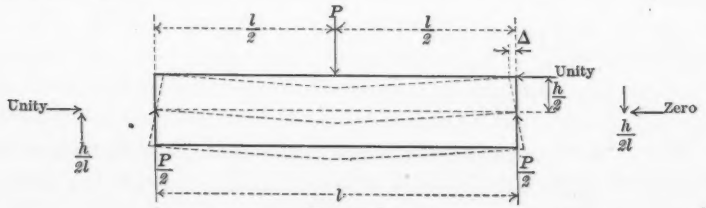


FIG. 1.

*This formula was first derived by Professor Fraenkel.

Taking each half of the beam separately, and taking the ends of the neutral axis of the beam as the origin of x, we have:

$$\Delta = \int_o^l \frac{M m\, dx}{EI} = \int_o^{\frac{l}{2}} \frac{M m\, dx}{EI} \text{ for the left half}$$

$$+ \int_o^{\frac{l}{2}} \frac{M m\, dx}{EI} \text{ for the right half,}$$

in which,

$$M = + \frac{P}{2} \times x, \text{ for both right and left halves of the beam,}$$

$$m = + \frac{h}{2l} \times x, \text{ for the left half of the beam,}$$

and $m = - \frac{h}{2l} \times x + \frac{h}{2}$, for the right half of the beam.

Substituting these values for M and m in the general equation, we have:

$$\Delta = \int_o^{\frac{l}{2}} \frac{P h x^2\, dx}{4 l EI} - \int_o^{\frac{l}{2}} \frac{P h x^2\, dx}{4 l EI} + \int_o^{\frac{l}{2}} \frac{P h x\, dx}{4 EI}$$

$$= \int_o^{\frac{l}{2}} \frac{P h x\, dx}{4 EI} = \frac{P h l^2}{32 EI}.$$

If m make $P = 29\,000$, $l = 360$ ins. and $I = 1\,140$ (inches ^{4th}), this being the value for the moment of inertia of a 20-in. I-beam (192 lbs. per yard), then:

$$\Delta = \frac{29\,000 \times 20 \times (360)^2}{32 \times 29\,000\,000 \times 1\,140} = \frac{1}{14} \text{ in. nearly.}$$

In the problems of practice it is usually the vertical deflection of some point in a horizontal beam under vertical loading that is desired, The following five problems are deemed sufficient to show the application of the general formula to finding such deflections. The girders in the following problems have four values for the moment of inertia; the resulting expressions for the deflections, however, are of such form that expressions for the value of the deflection for a girder with a greater or less number of values of the moment of inertia can be written by inspection. For girders with inclined flanges values of the moment of inertia can be determined at stated intervals, and these values considered constant for the intervals taken.

Problem No. 1.—Find the vertical deflection at the center of a plate-girder span with three cover-plates, the girder being loaded uniformly

throughout its length, l, with a vertical load of w pounds per unit of length. Fig. 2 will make the problem more clear.

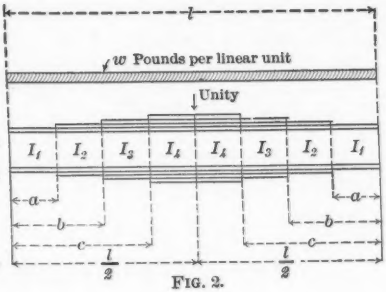


FIG. 2.

As the moment of inertia of the girder has four values, the second part of the general equation,

$$\Delta = \int_o^l \frac{M m \, dx}{EI} = 2\int_o^{\frac{l}{2}} \frac{M m \, dx}{EI},$$

will have four parts:

$$\Delta = \frac{w}{2E}\int_o^a \frac{(lx^2 - x^3)\,dx}{I_1} + \frac{w}{2E}\int_a^b \frac{(lx^2 - x^3)\,dx}{I_2}$$

$$+ \frac{w}{2E}\int_b^c \frac{(lx^2 - x^3)\,dx}{I_2} + \frac{w}{2E}\int_c^{\frac{l}{2}} \frac{(lx^2 - x^3)\,dx}{I_4}$$

$$= \frac{w}{2E}\left\{\frac{la^3}{3I_1} - \frac{a^4}{4I_1} + l\frac{(b^3 - a^3)}{3I_2} - \frac{b^4 - a^4}{4I_2} + l\frac{(c^3 - b^3)}{3I_3}\right.$$

$$\left. - \frac{c^4 - b^4}{4I^3} + \frac{l(l^3 - 8c^3)}{24I_4} - \frac{l^4 - 16c^4}{64I_4}\right\}$$

$$= \frac{5}{384}\frac{wl^4}{EI_4} + \frac{wl}{6E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right)$$

$$- \frac{w}{8E}\left(\frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_4} - \frac{c^4}{I_4}\right)$$

which is the expression for the value of the desired deflection.

If $I_1 = I_2 = I_3 = I_4$, that is, if the moment of inertia of the beam be constant, the expression becomes:

$\Delta = \frac{5}{384}\frac{wl^4}{EI}$, which is the well-known formula for the deflection at the center of a simple beam of constant moment of inertia, under uniform loading.

Problem No. 2.—Find the vertical deflection at the center of a plate-girder span with three cover-plates, due to a vertical load, P, at any point in the span.

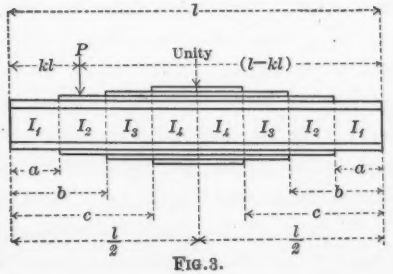


FIG. 3.

The load, P, will be placed on the first cover-plate, and the

expression found for the value of the deflection. The expression for the deflection for any desired position of P can then be written by inspection.

$$\Delta = \int_o^l \frac{M m \, dx}{E I}$$

$$= \int_o^a \frac{P(1-k)x^2 \, dx}{2EI_1} + \int_a^{kl} \frac{P(1-k)x^2 \, dx}{2EI_2}$$

$$+ \int_k^b \frac{Pk(lx - x^2) \, dx}{2EI_2} + \int_b^c \frac{Pk(lx - x^2) \, dx}{2EI_3}$$

$$+ \int_c^{\frac{l}{2}} \frac{Pk(lx - x^2) \, dx}{2EI_4} + \int_o^a \frac{Pkx^2 \, dx}{2EI_1} + \int_a^b \frac{Pkx^2 \, dx}{2EI_2}$$

$$+ \int_b^c \frac{Pkx^2 \, dx}{2EI_3} + \int_c^{\frac{l}{2}} \frac{Pkx^2 \, dx}{2EI_4}$$

$$= \frac{P(1-k)}{6E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{k^3 l^3}{I_2}\right)$$

$$+ \frac{Pk}{4E}\left(\frac{lb^2}{I_2} - \frac{lb^2}{I_3} + \frac{lc^2}{I_3} - \frac{lc^2}{I_4} + \frac{l^3}{4I_4} - \frac{l^3k^2}{I_2}\right)$$

$$- \frac{Pk}{6E}\left(\frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4} + \frac{l^3}{8I_4} - \frac{k^3l^3}{I_2}\right)$$

$$+ \frac{Pk}{6E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4} + \frac{l^3}{8I_4}\right)$$

$$= \frac{P}{6E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2}\right) - \frac{Pk^3l^3}{12EI_2}$$

$$+ \frac{Pkl}{4E}\left(\frac{b^2}{I_2} - \frac{b^2}{I_3} + \frac{c^2}{I_3} - \frac{c^2}{I_4}\right) + \frac{Pkl^3}{16EI_4},$$

which is the expression for the value of the desired deflection.

For a load, P, on the second cover-plate, by inspection, can be written:

$$\Delta = \frac{P}{6E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3}\right) - \frac{Pk^3l^3}{12EI_3}$$

$$+ \frac{Pkl}{4E}\left(\frac{c^2}{I_3} - \frac{c^2}{I_4}\right) + \frac{Pkl^3}{16EI_4}.$$

If we make $I_1 = I_2 = I_3 = I_4$, in either of the above values for Δ, we have:

$\Delta = \frac{Pkl^3}{48EI}(3 - 4k^2)$, and if $k = \frac{1}{2}$, that is, for P in the center of the girder,

$$\Delta = \frac{Pl^3}{48EI}.$$

Problem No. 3.—Find the vertical deflection at the loaded point of a plate-girder span with three cover-plates, due to a vertical load, P, at any point in the span.

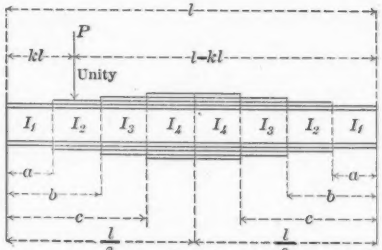


FIG. 4.

P will be placed on the first cover-plate, as in Problem No. 2.

$$\Delta = \int_o^l \frac{M\,m\,dx}{E\,I}$$

$$= \int_o^a \frac{P\,(1-k)^2\,x^2\,dx}{E\,I_1} + \int_a^{kl} \frac{P\,(1-k)^2\,x^2\,dx}{E\,I_2}$$

$$+ \int_{kl}^b \frac{P\,k^2\,(l-x)^2\,dx}{E\,I_2} + \int_b^c \frac{P\,k^2\,(l-x)^2\,dx}{E\,I_3}$$

$$+ \int_c^{\frac{l}{2}} \frac{P\,k^2\,(l-x)^2\,dx}{E\,I_4} + \int_o^a \frac{P\,k^2\,x^2\,dx}{E\,I_1}$$

$$+ \int_a^b \frac{P\,k^2\,x^2\,dx}{E\,I_2} + \int_b^c \frac{P\,k^2\,x^2\,dx}{E\,I_3} + \int_c^{\frac{l}{2}} \frac{P\,k^2\,x^2\,dx}{E\,I_4}$$

$$= \frac{P\,(1-k)^2}{3\,E}\left(\frac{a^3}{I_1} + \frac{k^3\,l^3}{I_2} - \frac{a^3}{I_2}\right)$$

$$+ \frac{P\,k^2\,l^2}{E}\left(\frac{b}{I_2} - \frac{k\,l}{I_2} + \frac{c}{I_3} - \frac{b}{I_3} + \frac{l}{2\,I_4} - \frac{c}{I_4}\right)$$

$$- \frac{P\,k^2\,l}{E}\left(\frac{b^2}{I_2} - \frac{k^2\,l^2}{I_2} + \frac{c^2}{I_3} - \frac{b^2}{I_3} + \frac{l^2}{4\,I_4} - \frac{c^2}{I_4}\right)$$

$$+ \frac{P\,k^2}{3\,E}\left(\frac{b^3}{I_2} - \frac{k^3\,l^3}{I_2} + \frac{c^3}{I_3} - \frac{b^3}{I_3} + \frac{l^3}{8\,I_4} - \frac{c^3}{I_4}\right)$$

$$+ \frac{P\,k^2}{3\,E}\left(\frac{a^3}{I_1} + \frac{b^3}{I_2} - \frac{a^3}{I_2} + \frac{c^3}{I_3} - \frac{b^3}{I_3} + \frac{l^3}{8\,I_4} - \frac{c^2}{I_4}\right)$$

$$= \frac{P\,l^3\,k^2}{3\,E}\left(\frac{1}{I_4} - \frac{2\,k}{I_2} + \frac{k^2}{I_2}\right) + \frac{P\,(1-2\,k)}{3\,E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2}\right)$$

$$+ \frac{P\,k^2\,l^2}{E}\left(\frac{b}{I_2} - \frac{b}{I_3} + \frac{c}{I_3} - \frac{c}{I_4}\right)$$

$$- \frac{P\,k^2\,l}{E}\left(\frac{b^2}{I_2} - \frac{b^2}{I_3} + \frac{c^2}{I_3} - \frac{c}{I_4}\right)$$

$$+ \frac{2\,P\,k^3}{3\,E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_4} - \frac{c^3}{I_4}\right),$$

which is the expression for the value of the desired deflection.

If we make $I_1 = I_2 = I_3 = I_4$, then

$\Delta = \dfrac{P\,l^3\,k^2\,(1-k)^2}{3\,E}$, and, in addition, if we make $k = \dfrac{1}{2}$, then

$$\Delta = \frac{P\,l^3}{48\,E\,I}.$$

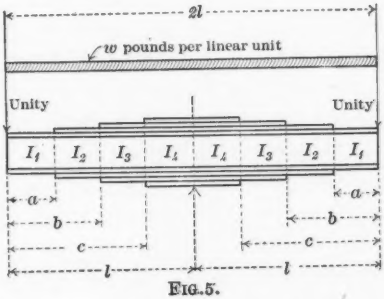


FIG. 5.

Problem No. 4.—Find the vertical deflections of the ends of a plate-girder span with three cover-plates, supported at the center, only, and loaded with a uniform vertical load, w, per unit of length.

$$\Delta = \int_o^l \frac{M\,m\,dx}{E\,I}$$

$$= \int_o^a \frac{w\,x^3\,dx}{2\,E\,I_1} + \int_a^b \frac{w\,x^3\,dx}{2\,E\,I_2} + \int_b^c \frac{w\,x^3\,dx}{2\,E\,I_3} + \int_c^l \frac{w\,x^3\,dx}{2\,E\,I_4}$$

$$= \frac{w}{8\,E}\left(\frac{a^4}{I_1} + \frac{b^4}{I_2} - \frac{a^4}{I_2} + \frac{c^4}{I_3} - \frac{b^4}{I_3} + \frac{l^4}{I_4} - \frac{c^4}{I_4}\right)$$

$$= \frac{w\,l^4}{8\,E\,I_4} + \frac{w}{8\,E}\left(\frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right)$$

which is the expression for the value of the desired deflection.

If $I_1 = I_2 = I_3 = I_4$, then,

$$\Delta = \frac{w\,l^4}{8\,E\,I}.$$

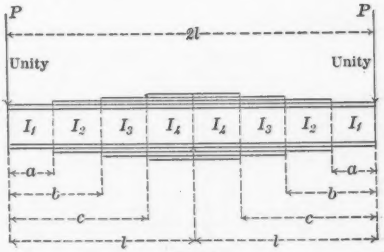


FIG. 6.

Problem No. 5.—Find the vertical deflection of the ends of a plate-girder span with three cover-plates, supported at the center, only, and loaded at each end with a load, P.

$$\Delta = \int_o^l \frac{M\,m\,dx}{E\,I}$$

$$= \int_o^a \frac{P\,x^2\,dx}{E\,I_1} + \int_a^b \frac{P\,x^2\,dx}{E\,I_2} + \int_b^c \frac{P\,x^2\,dx}{E\,I_3} + \int_c^l \frac{P\,x^2\,dx}{E\,I_4}$$

$$= \frac{P}{3\,E}\left(\frac{a^3}{I_1} + \frac{b^3}{I_2} - \frac{a^3}{I_2} + \frac{c^3}{I_3} - \frac{b^3}{I_3} + \frac{l^3}{I_4} - \frac{c^3}{I_4}\right)$$

$$= \frac{P\,l^3}{3\,E\,I_4} + \frac{P}{3\,E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right)$$

which is the expression for the value of the desired deflection.

If $I_1 = I_2 = I_3 = I_4$, then,

$$\Delta = \frac{P\,l^3}{3\,EI}.$$

By substituting for Δ, in the above expression, the distance it is desired to raise the end of a plate-girder draw, and solving for P, the uplift necessary to raise the end the desired amount is obtained.

In applying the results of the preceding problems a deduction of 2 or 3 ft. from the over-all lengths of the cover-plates should be made, for the reason that enough rivets to fully develop the value of a cover-plate to resist stress are not generally contained in a less distance than the first 2 or 3 ft. at the end of the cover-plate.

By the aid of the results of Problems Nos. 4 and 5, the reactions for center-bearing plate-girder draw spans, with equal arms under uniform loading, can be obtained.

Let $R_1 = R_3$ be the reactions at the ends of a two-span plate-girder with three cover-plates. From the result of Problem No. 5, we have, for the vertical motion, Δ, due to a force, $R_1 = R_3$, at the ends, the following:

$$\Delta = \frac{R_1\,l^3}{3\,EI_4} + \frac{R_1}{3\,E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right)$$

If, at the same time, we make the value for Δ given by the result of Problem No. 4 equal to the value for Δ above, and solve the equation for R_1, we have:

$$R_1 = R_3 = \frac{\frac{w\,l^4}{8\,I_3} + \frac{w}{8}\left(\frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right)}{\frac{l^3}{3\,I_4} + \frac{1}{3}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right)}$$

$$= \frac{3\,w}{8}\,\frac{\frac{l^4}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}}{\frac{l^3}{I_4} + \frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}}$$

which is the expression for the value of the end reactions for a plate-girder of two equal spans having four values for the moment of inertia, and loaded uniformly throughout its length by w pounds per unit of length.

If $I_1 = I_2 = I_3 = I_4$, then $R_1 = R_3 = \frac{3}{8}\,w\,l$.

It would not be a difficult matter to derive values for the reactions for a more general case of loading and span lengths; but the ordinary

plate-girder draw has equal arms, and the only place, under the general practice in designing, where it is necessary to consider the effect of continuous loading is near and over the center support. The maximum values for shear and moment at the center support are given under conditions closely approximating continuous uniform load, and this is the problem we have solved.

In order to see how much the ordinary method (using a constant moment of inertia) of computing the moments over the center supports of plate-girder draws differs from this more exact method, the comparison will be made for two widely different cases.

Case I.—A very light, single-track, center-bearing, plate-girder draw, 72½ ins. deep, from out to out of flange-angles.

		Length over all.		Effective length.
1 web plate,	72 × ⅜ ins.	138 ft.	and	136 ft.
4 flange-angles,	5 × 5 "	138 "	"	136 "
(55 lbs. per yard.)				
2 cover-plates,	12 × ⅝ "	98 "	"	96 "
2 " "	12 × ⅝ "	22 "	"	20 "
2 " "	12 × ⅝ "	10 "	"	8 "

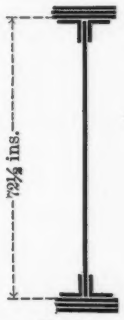


FIG. 7.

$I_1 = 38\,284$ ins.$^4 = 1.85$ ft.^{4} and $a = 20$ ft.
$I_2 = 58\,335$ " $= 2.81$ " $b = 58$ "
$I_3 = 79\,081$ " $= 3.81$ " $c = 64$ "
$I_4 = 100\,526$ " $= 4.85$ " $l = 68$ "

$$\frac{a^3}{I_1} = 4\,324.3, \quad \frac{a^3}{I_2} = 2\,847.0, \quad \frac{a^4}{I_1} = 8\,648.6, \quad \frac{a^4}{I_2} = 5\,694.0,$$

$$\frac{b^3}{I_2} = 69\,434.9, \quad \frac{f^3}{I_3} = 51\,210.5, \quad \frac{b^4}{I_2} = 4\,027\,206.3, \quad \frac{b^4}{I_3} = 2\,970\,209.0,$$

$$\frac{c^3}{I_3} = 68\,804.2, \quad \frac{c^3}{I_4} = 54\,050.3, \quad \frac{c^4}{I_3} = 4\,403\,468.8, \quad \frac{c^4}{I_4} = 3\,459\,219.8,$$

$$\frac{l^3}{I_4} = 64\,831.3 \qquad \frac{l^4}{I_4} = 4\,408\,531.1,$$

$$+ = 207\,394.7, \quad - = 108\,107.8, \quad + = 12\,847\,854.8, \quad - = 6\,435\,122.8,$$

$$R_1 = \frac{3}{8} w \; \frac{\frac{l^4}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}}{\frac{l^3}{I_4} + \frac{a^3}{I_1} - \frac{a^3}{I_3} + \frac{b^3}{I_3} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}}$$

$$= \frac{3}{8} w \; \frac{12\,847\,854.8 - 6\,435\,132.8}{207\,394.7 - 108\,107.8} = \frac{3}{8} w \, 64.59 = 24.22 \, w.$$

The moment over the center support for this case is:

$M = 68\ w\ (24.22 - 34.00) = -\ 665.04\ w$ foot-pounds.

The moment over the center support for constant moment of inertia is:

$$M = -\frac{1}{8} w\ l^2 = -\ 578\ w \text{ foot-pounds,}$$

which shows that this more exact method gives a moment over the center support for this case 15% greater than the usual method.

Case II.—A very heavy, double-track, center-bearing, plate-girder draw, 101½ ins. deep, from out to out of flange angles.

		Length over all.		Effective length.
1 web plate,	$101 \times \frac{11}{16}$ ins.,	159 ft.	and	156 ft.
4 side flange-plates,	$18 \times \frac{3}{4}$ "	159 "	"	156 "
4 flange angles,	8×6 "	159 "	"	156 "
	(125 lbs. per yard.)			
2 cover-plates,	$20 \times \frac{3}{4}$ "	159 "	"	156 "
2 " "	$20 \times \frac{3}{4}$ "	84 "	"	82 "
2 " "	$20 \times \frac{3}{4}$ "	24 "	"	22 "
2 " "	$20 \times \frac{3}{4}$ "	16 "	"	14 "

$I_1 = 353\ 750$ ins.^{4} $= 17.06$ ft.^{4} and $a = 37$ ft.
$I_2 = 434\ 500$ " $= 20.96$ " " $b = 67$ "
$I_3 = 517\ 600$ " $= 24.96$ " " $c = 71$ "
$I_4 = 603\ 100$ " $= 29.08$ " " $l = 78$ "

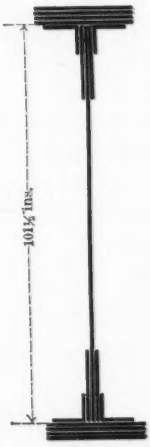


FIG. 8.

$$\frac{a^3}{I_1} = 2\ 969.1,\ \frac{a^3}{I_2} = 2\ 416.7,\ \frac{a^4}{I_1} = 109\ 857.3,\ \frac{a^4}{I_2} = 89\ 416.1,$$

$$\frac{b^3}{I_2} = 14\ 349.4,\ \frac{b^3}{I_3} = 12\ 049.9,\ \frac{b^4}{I_2} = 961\ 408.5,\ \frac{b^4}{I_3} = 807\ 336.6,$$

$$\frac{c^3}{I_3} = 14\ 339.3,\ \frac{c^3}{I_4} = 12\ 307.8,\ \frac{c^4}{I_3} = 1\ 018\ 096.2,\ \frac{c^4}{I_4} = 873\ 854.2,$$

$$\frac{l^3}{I_4} = 16\ 318.8, \qquad \frac{l^4}{I_4} = 1\ 272\ 869.9$$

$$+ = \overline{47\ 976.6} \quad - = \overline{26\ 774.4} \quad + = \overline{3\ 362\ 231.9} \quad - = \overline{1\ 770\ 606.9},$$

$$R_1 = \frac{3}{8} w \frac{3\ 362\ 231.9 - 1\ 770\ 606.9}{47\ 976.6 - 26\ 774.4} = \frac{3}{8} w\ 75.07 = 28.15\ w.$$

The moment over the center support, for this case, is:

$M = 78\ w\ (28.15 - 39.00) = -\ 846.30\ w$ foot-pounds.

The moment over the center support, for constant moment of inertia, is:

$$M = -\frac{1}{8} w l^2 = 760.5\ w \text{ foot-pounds.}$$

Which shows that this more exact method gives a moment over the center support for this case 11% greater than the usual method.

The two plate-girder drawbridges selected for investigation may be said to represent fairly the results obtained by the method commonly used in designing such structures. In view of the results of the investigation for these two cases, it is fair to assume that many center-bearing plate-girder drawbridges are stressed considerably higher, for a short distance over the center support, than their designers intended they should be. This condition of affairs, it is believed, is quite generally known, but, as far as the writer knows, has not influenced designers. The additional material required for a more correct design is a very small percentage of the whole weight, and, considering the increased strength it would give, the addition should always be made.

The objection may be made that it is hardly necessary to go to any great refinement in designing plate-girder drawbridges, as it is not certain that the end machinery will act as designed, and, further, even though the condition of the supports be as assumed, until account is taken of the effect of the shearing stresses in producing distortion, the true reactions cannot be obtained. The fact that the end supports may be out of their proper position, and in such a manner as to cause increased bending moments over the center support, is an argument in favor of the most refined methods in designing the structure. It is not customary to consider the effect of the shearing stresses in producing distortion, in designing plate-girder drawbridges; the method used in investigating Case I and Case II is simply a more refined application of the usual method (which considers only flexural stresses). In order to determine the effect of the shearing stresses in producing deflection, the following investigation is made:

Let us take any portion of a beam in equilibrium under the action of transverse loading, as shown in Fig. 9. If P be the resultant in position, direction and amount of all the forces to the right of the section $m\ n$, then it is clear that

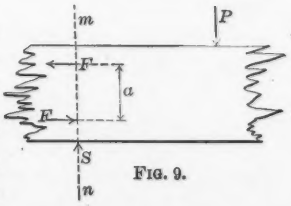


FIG. 9.

the portion of the beam under consideration would be kept in equilibrium by the couple, Fa, and the shear, S.

In general, no matter what may be the actual distribution of the stresses on any section of a beam under a given loading, these stresses may be resolved into an equivalent couple and shear. The effect of the couple in doing work has been determined in accordance with the common theory of flexure. Going back to (1), and rewriting the expression for the work of the internal stresses, we have

$$w = \left(\int_o^l \frac{Mm\,dx}{2EI} \text{ for the work of the flexural stresses}\right)$$
$$+\left(\int_o^l \frac{Ss\,dx}{2E_sA} \text{ for the work of the shearing stresses}\right).$$

To derive the expression for the work done by the shearing stresses:

Let S = shear at any point, due to the given loading;

s = shear at any point, due to a load of unity at the point where deflection is desired;

A = total area of the cross-section;

E_s = coefficient of elasticity for shear;

and let dx be an infinitesimal portion of the length of the beam; that is, let it be considered as the distance between two consecutive sections of the beam.

Then, under the action of the shearing stress, S, the two consecutive sections will have a relative motion of $\frac{S\,dx}{AE_s}$, if we assume that the shearing stress is distributed uniformly over the cross-section.

Now, as for the flexural stresses, we will suppose the force of unity to be applied gradually; then the work done by the shearing stress, on an elementary portion of the beam, due to the force of unity, is $\frac{S\,dx}{AE_s} \times \frac{s}{2}$, and, over the entire beam, the work is $\int_o^l \frac{Ss\,dx}{2E_sA}$.

Making the expressions for the external and internal work equal, we have:

$$\frac{\Delta}{2} = \int_o^l \frac{Mm\,dx}{2EI} + \int_o^l \frac{Ss\,dx}{2E_sA}, \text{ and}$$

$$\Delta = \int_o^l \frac{Mm\,dx}{EI} + \int_o^l \frac{Ss\,dx}{E_sA}.$$

The shearing stress is not distributed uniformly over the cross-section, and hence the term for the work of the shearing stress should

be modified by a coefficient. The value of this coefficient for a rectangular section is very readily shown to be $\frac{6}{5}$.

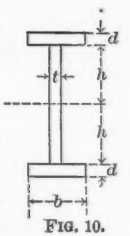


FIG. 10.

For a section, as shown in Fig. 10, which is a close enough approximation to plate-girder cross-sections, for all practical purposes, the work done by the shearing stresses due to unity, taking the intensity of the vertical shear as equal to the intensity of the horizontal shear at all points of the cross-section, on two flanges

$$= \frac{b\,[8\,(h+d)^5 - 15\,(h+d)^4\,h + 10\,(h+d)^2\,h^3 - 3\,h^5]}{30\,I^2} \int_o^l \frac{S\,s\,d\,x}{E_s}$$

and on the web

$$= \frac{30\,b^2\,d^2\,\frac{h}{t}\left(h+\frac{d}{2}\right)^2 + 20\,b\,d\,h^3\left(h+\frac{d}{2}\right) + 4\,h^5\,t}{30\,I^2} \int_o^l \frac{S\,s\,d\,x}{E_s}$$

The total work on the entire cross-section is the sum of these, and

$$= \frac{\begin{array}{l} 8\,b\,(h+d)^5 - 15\,b\,k\,(h+d)^4 + 10\,b\,h^3(h+d)^2 \\ \quad - 3\,b\,h^5 + 30\,b^2\,d^2\,\frac{h}{t}\left(h+\frac{d}{2}\right)^2 \\ \quad + 20\,b\,d\,h^3\left(h+\frac{d}{2}\right) + 4\,h^5\,t \end{array}}{30\,I^2} \int_o^l \frac{S\,s\,d\,x}{E_s}$$

This expression is of such an involved nature that a simple inspection gives very little information as to the relative value of the work on the flanges and web to that of the work on the entire cross-section. For the purpose of getting a definite idea of this relation, and, at the same time, for reinvestigating the plate-girders of Case I and Case II, approximate sections for the end and center of each of these girders will be assumed.

Case I.

Approximate end-section:	Approximate center-section:
$b = 12$ ins.	$b = 12$ ins.
$d = 1$ "	$d = 2$ "
$h = 36$ "	$h = 36$ "
$t = \frac{3}{8}$ "	$t = \frac{3}{8}$ "
Work on flanges = 0.0003	Work on flanges = 0.0008
Work on web = 0.9997	Work on web = 0.9992

Case II.

Approximate end-section:	Approximate center-section:
$b = 20$ ins.	$b = 20$ ins.
$d = 2$ "	$d = 4$ "
$h = 50$ "	$h = 50$ "
$t = \frac{3}{4}$ "	$t = \frac{3}{4}$ "
Work on flanges $= 0.0006$	Work on flanges $= 0.0013$
Work on web $= 0.9994$	Work on web $= 0.9987$

From this it is seen that the amount of work done on the flanges is a very small part of the total work on the cross-section. A similar investigation on a section more closely approximating the actual cross-section of a plate-girder, as shown in Fig. 11, would show a considerably larger amount of work for the flanges; but it would still be very small. Therefore, in investigating the effect of shear in producing distortion on plate-girders it will be very nearly correct to assume that the web alone resists all the shearing stresses. This assumption would give deflections a little too great, as the flanges of a plate-girder do take a small part of the shear—for a plate-girder such as that in Case II the vertical flange plates and the vertical legs of the flange-angles take considerable shear; however, in the investigation to follow, the effect of the unequal distribution of the shear over the web will be neglected.



FIG. 11.

This assumption produces an error opposite to and generally greater than the first assumption, so that the resulting deflections determined under these assumptions will be very nearly correct, but probably a trifle too small.

The general equation for the deflection of a plate-girder of varying cross-section now becomes

$$\Delta = \int_o^l \frac{M\,m\,dx}{E\,I} + \int_o^l \frac{S\,s\,dx}{E_s\,A_w}, \text{ in which } A_w = \text{area of web.}$$

Making $E_s = \frac{2}{5}\,E$, the deflection

$$\Delta = \int_o^l \frac{M\,m\,dx}{E\,I} + \frac{5}{2}\int_o^l \frac{S\,s\,dx}{E\,Aw}.$$

From this the expression for the value of the deflection for Problem No. 4 becomes

$$\Delta = \frac{w}{8\,E}\left(\frac{l^4}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right) + \frac{5}{4}\,\frac{w\,l^2}{E\,A_w};$$

and for Problem No. 5 it becomes

$$\Delta = \frac{P}{3E}\left(\frac{l^3}{I_4} + \frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right) + \frac{5}{2}\frac{w\,l^2}{E\,A_w}$$

The expression for the value of the end reactions for a plate-girder of two equal spans, the girder having four values of I, and loaded uniformly throughout its length by w pounds per unit of length, is:

$$R_1 = R_3$$

$$= \frac{3}{8} w \frac{\left(\frac{l}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right) + \frac{10\,l^2}{A_w}}{\left(\frac{l^3}{I^4} + \frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^4}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right) + \frac{15\,l}{A_w}}.$$

Using this expression in investigating Case I and Case II:

For Case I:

$$R = \frac{3}{8} w \frac{6\,412\,732 + 246\,613}{99\,287 + 2\,720} = \frac{3}{8} w \times 65.28 = 24.48\ w;$$

and the moment over the center support,

$$M = 68\ w\ (24.48 - 34.00) = -647.36\ w \text{ foot-pounds.}$$

This moment is only 2.6% less than that found by the first investigation for Case I.

For Case II:

$$R = \frac{3}{8} w \frac{1\,591\,625 + 126\,165}{21\,202 + 1\,213} = \frac{3}{8} w \times 76.64 = 28.74\ w;$$

and the moment over the center support,

$$M = 78\ w\ (28.74 - 39.00) = -800.28\ w \text{ foot-pounds.}$$

This moment is 5.5% less than that found by the first investigation for Case II.

The result of this reinvestigation for Case I and Case II shows: For the shorter and lighter draw-span, that the deflection of the end of the span, due to the shearing stresses caused by uniform loading, is about 4% of that due to the flexural stresses from the same cause; that the deflection of the end of the span due to the shear caused by a load at the end is about 3% of that due to the flexural stresses from the same cause; and that the calculated moment over the center support, obtained by a consideration of the flexural stresses alone, is about 2.6% greater than that obtained by taking into account the effect of the shearing stresses.

For the longer and heavier draw-span, the consideration of the effect of the shearing stresses shows differences about twice as great, in each instance, as was shown for the shorter and lighter structure.

That the effect of the shearing stresses should be greatest in the long girder, does not seem to be in accord with the fact that, for a beam of constant cross-section, the relative effect of the shearing stresses is less the longer the span; an inspection of all the elements of the problem shows that the much larger moment of inertia and the relatively less area in the web of the long girder are more than sufficient to overcome the effect of its greater length. In view of the results of this investigation it would seem to be necessary to consider the effect of the shearing stresses, in modifying the effect of the flexural stresses in designing, only for very deep girders subject to very heavy loads. The amount of labor required for a proper consideration of the shearing stresses is very small, so that whenever great accuracy is required they should always be considered.

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PAPERS AND DISCUSSIONS.

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THE PANAMA CANAL.

Discussion.*

By Messrs. M. Meigs, Theodore Paschke, C. L. Harrison, P. Bunau-Varilla and George S. Morison.

M. Meigs, M. Am. Soc. C. E. (by letter).—This extremely interesting paper on the Panama Canal and its problems will appeal strongly to all engineers, and no doubt awaken wide discussion. So far, the writer has not been able, from the discussion on the papers on the Isthmian Canal problem he has seen, to discover whether the Chagres is a mountain torrent of clear water, rolling stone, gravel and sand along its bed, or a silt-bearing stream, charged with mud as well as sand. In his opinion, there is a vast difference between the two, not alone as affecting the cost of the up-keep of the canal, but also the practicability of the scheme, now little talked of, for a sea-level canal, and as related to the problem of the Bohio Dam. Mr. Meigs.

The writer has had twenty years' experience on a canal, 7½ miles long and 250 to 350 ft. wide, on the Mississippi River, at Keokuk, Iowa. This canal receives the, at times, muddy water of the river, necessary to feed it and to provide for lockage; and, in addition, two small creeks and a few short watercourses empty directly into the canal. The rainfall in this latitude is only 40 ins., as against 200 ins., or thereabout, on the Isthmus, and yet it requires the almost constant attention of a dredge to keep the channel open for navigation.

*This discussion (of the paper by George S. Morison, Past-President, Am. Soc. C. E., printed in *Proceedings* for January, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to April 24th, 1903, will be published subsequently.

Mr. Meigs. In the twenty years of the writer's connection with the canal, 1 600 000 cu. yds. of mud, sand and gravel have been removed from the canal prism in a length of not more than 5 miles; two deep pools at the lower ends of reaches of the canal not yet having shoaled sufficiently to require dredging, and aggregating about 2 miles of the 7½ miles of canal.

On several occasions a single storm, lasting not 24 hours, has thrown enough material into the canal to keep a large Osgood dredge at work for a month removing it, working night and day 16 out of the 24 hours. It would seem that any sea-level plan would be negatived by the dredging requirements necessary to keep the channel open. With a 32-ft. boat it would require but a small rush of water from some side stream to cause a stoppage of navigation. The sea-level canal, necessarily, would be the recipient of all the débris washed down the tributary streams. A large rock rolled into the channel would cause the sinking of the first heavy-draft steamer that came along, and, in fact, the delays and expense would be interminable.

At the Keokuk Canal a sluice in the upper level allows of a short tow for the dredge tender, as the sluice is used to wash the dredged material into the river by opening certain gates. At Panama there would seem to be no method of getting rid of the material dredged except by elevating it to the sides of the canal, or by towing it out to sea. Either of these methods would be slow and very costly. Even if there is clear water at all times, there will be, for a sea-level canal, constant trouble at the mouth of every creek and river. It is true that dams along the course of these streams would retain a portion of the débris for a time, but they would soon fill up, and dredging would have to be the result in the end. This has happened already to the Keokuk Canal. From a dredging standpoint, the sea-level canal looks like an impossibility.

All this is changed in the admirable high-level reservoir and lock scheme worked out by the Canal Commission and Mr. Morison. Whether bearing silt, or only sand and gravel, Lake Bohio will perform a most valuable office in providing a settling ground for the water used in the canal. No doubt the greater part of the sediment will remain in the lake, and the necessity for constant dredging in the canal prism will be avoided for a long time.

Mr. Morison's design for a temporary dam seems to the writer to be sufficiently good for the permanent structure. There seems to be no reason why iron should not be adopted as the material for permanent and high dams. It should be remembered that such a dam as sketched in Mr. Morison's paper on "The Bohio Dam" can be made absolutely tight. The construction would afford a view of the lower side of the dam at all times, and all leakage could be detected and stopped at any time. If kept painted, it would rust only on the upper

Mr. Meigs.

side, and the rate of deterioration would be very small. Wrecks of vessels thirty years and more under water, on the upper part of the Mississippi River, show in their ironwork but little loss from rust. A brown scale is formed on the surface, looking like brown varnish, and this seems to protect the iron.

If the dam were built early in the progress of the work, would it not, by means of the lake, give a cheap means of transporting the spoil from the prism of the canal? That spoil, dumped from barges above the dam, would, in the course of the construction of the canal, fill the valley, and would make a dam that would be absolutely beyond suspicion, and at little comparative expense where the work is almost entirely a cut As for percolation, it would cut that off entirely, for it seems to the writer that the percolation has been more dreaded than there is any occasion for. If Mr. Morison's iron dam were merely set upon a broad sheet of concrete extending some distance above the dam, and the bearing under the dam were fortified by driving plenty of round piling to give a firm foundation and also to consolidate the soil; if this dam were built between abutments of stone, with an earth embankment beginning at the point where it would be possible to reach bed-rock with caissons, thus securing a tight connection with the bottom of the geological valley; and if, under the sheet of concrete, several rows of sheet-piles, preferably of iron, like the dam, were driven across the valley from one abutment to the other, the writer thinks that the foundation of the dam, and the percolation beneath it, would be sufficiently guarded, without having to go to the unparalleled depth for foundations, which, in the minds of many engineers, seems to be necessary. There are, in India, tanks, as they are called, which are formed by earth dams of heights equal to the Bohio Dam, and they have stood for centuries. Some of these dams, it is said, were built by sluicing material from the adjoining hills in troughs fed by the mountain streams in the vicinity. It is not likely that the people who built those dams went into refinements about bed-rock foundations.

On the section marked *B**, on the map of dam sites, it would seem, from rough calculation, that a dam might be constructed consisting of 350 ft. of embankment at each end and a connecting section of iron, not more than 550 ft. long. This iron dam would be about 100 ft. high, but what better or more trusty material can be found? The calculation of the forces entering into the problem are simple, too; much simpler than in the case of a bridge, and the material would be used economically. The work could be done in a temperate climate—all but the setting up—and, during erection, the river could be allowed to flow between the bents until the final moment of closure. It is this feature—of doing most of the work in high-class shops and shipping it out ready to erect—that most commends itself. Finally, if this

* The "Bohio Dam." *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 239.

Mr. Meigs. dam were erected early, and, on being tested, were found wanting, it could be replaced with some other structure, without interfering with the opening of the canal. The writer cannot help thinking that Mr. Morison's estimate for the earth dam is too low, though, if built, it would certainly solve the problem.

Mr. Paschke. THEODORE PASCHKE, M. Am. Soc. C. E. — Mr. Morison's plan for a tide-level canal, as outlined in his excellent paper, is a very attractive one, and must appeal to all engineers and others who take any interest whatever in the question.

Heretofore, the control of the Chagres River, has been the great stumbling block in the way of a sea-level canal. The International Technical Commission, under the leadership of the genial de Lesseps, in declaring for a sea-level canal at Panama, certainly showed no lack of boldness in conception or assertion. But "'twas easier said than done."

As far as the writer is aware, no tangible, practical plan for the control of the Chagres, beyond a proposition to dam the river at Alhajuela and divert its waters, from the reservoir thus formed, through a new channel to the sea at a sufficient distance from the canal, had been evolved. The managers of the enterprise at Paris evidently depended upon the many eminent engineers who were sent out to the Isthmus to solve the problem in all its working details on the spot.

These, in turn, for the most part unused to accommodating themselves to the new and strange surroundings, unnerved by the debilitating influence of the climate, and over-awed by the apparent impenetrability of a tropical jungle and the magnitude of the problem before them, threw up their hands in despair and either fell victims to the pernicious fevers, or, if survivors, were subdued in spirit.

The rest of the story—the prodigality of the management, the subsequent exhaustion of funds and the final abandonment of the sea-level canal in favor of a lock canal—is a matter of history, and needs no further mention.

This grand failure to make good the decree of the International Technical Commission has been like a ban upon the project of a sea-level canal with the majority of engineers ever since. Therefore, it is refreshing and reassuring to have an engineer of Mr. Morison's standing come out with a proposition for a tide-level canal on entirely new lines; on lines of such bold simplicity that at once they not only assure the feasibility of the plan, but call forth an unstinted admiration for the author's sagacity, and give evidence of his fitness to deal with such problems.

The plan, as outlined in the paper, seems to have been left, probably intentionally, in a somewhat incomplete form, so as to invite criticism and discussion. As far as the plan is outlined by the author, the speaker has no criticism to offer, but only desires to point out

certain natural conditions and features in connection therewith, which, when properly adjusted, may tend to assist in making those outlines a little more definite. Mr. Paschke.

Mr. Morison, by calculations based upon reliable data, regarding the discharge of the Chagres River, has drawn the conclusion that it would require a canal 400 ft. in width to accommodate the maximum ordinary flood discharge without injury to the canal; with the reservation that this width might prove inadequate for a repetition of a flood like that of 1879. On this the speaker has only one comment to make, and that is: Why draw the limit at a width of 400 ft.? Having gone that far, it would be as well to go a little farther and obtain an adequate factor of safety. However, the speaker quite agrees with Mr. Morison that the construction of a dam at Alhajuela would be a more rational measure, not only for the control of the Chagres waters, but for another reason to be mentioned directly.

Mr. Morison has given the average elevation of the bed of the Chagres at Gamboa as 45 ft. above tide level, and the elevation of the bottom of the canal as 35 ft. below. This makes a fall of 80 ft. from the bed of the river to the bottom of the canal. A discharge of 70 000 cu. ft. per second over a precipice 80 ft. high almost makes one think of Niagara. It is plain that something must be provided to meet this condition. Some sort of a receiving basin or pool, of adequate dimensions, will have to be excavated, to bring the waters to rest, so that they may enter the canal quietly.

The contemplation of this feature naturally leads to another question: What becomes of the detritus and the sediment brought down by the river during floods? How is that to be taken care of?

It is to be regretted that so little consideration has been given this subject by the various commissions and engineers who, of late, have reported and written upon the problem of an Isthmian Canal. This subject is a very important feature in any proposition for the control of the Chagres River, and, if ignored in the formulation of the plans, will force itself, sooner or later, upon the operators of the canal when completed. It would be well to have some systematic observations upon this subject made during the coming rainy season, to ascertain the amount and character of the sediment carried in suspension by the Chagres River during floods.

The topography of Central America has a character peculiar to itself. It is volcanic, throughout. The underlying rocks are covered with deep layers of volcanic ashes or dust, of varying fineness, giving the country, in its principal features, a soft, undulating profile, which is only pierced here and there by groups of volcanic cones, for the most part now silent, but bearing witness of a former activity.

The accentuations which occur in the landscape are principally due to the action of water. This action of furrowing the surface

Mr. Paschke. and deepening and widening the cañons or barrancos down to bed-rock is still going on, and may be observed in any of the mountain streams during a flood. An inspection of the steep banks will reveal, like an open book, the character and thickness of the various layers of volcanic dust or ashes, and give in unmistakable language an account of the magnitude of the process necessary for the formation of these covering strata. With the exception of a few isolated cases, very little evidence has come under the speaker's observation to show that in the latter part of the eruptive period of that country, flows of liquid rock or lava have taken place. It seems that during this period, the eruptive material has only been ashes or dust, or these materials mixed with water as liquid mud. This latter observation has been verified by the many traditions among the aboriginal inhabitants relating to water- or mud-throwing volcanoes.

Most of this volcanic material has attained a certain consistency, a certain degree of hardness or cohesiveness, which allows it to stand, when pierced by an excavation like that for a railroad cut, with a slope approaching very nearly to the vertical. In fact, the speaker's experience has been, that the nearer to the vertical the faces of these slopes are kept, the better they stand, provided the surface drainage above is properly taken care of. The reason for this is, that, in the first place, it is a characteristic of most of this volcanic material, that its surface, when exposed to atmospheric influence, hardens slightly, giving it a crust-like protection; secondly, the nearly vertical face is not exposed to the action of the tropical rain torrents to such an extent as a face at the ordinary and customary slope of 1 to 1. However, on the other hand, all this material yields easily to erosion by flowing water. This may be traced out readily in any of the mountain streams of that country.

When exposed to the action of flowing water this material is reduced quickly to its original form, the coarser particles, in the form of sand, are carried down stream, a varying distance, but the finer particles, which in some cases form by far the greater portion of the mass, are carried off in complete suspension, in which condition they are held for a long time. Even when the speed of the flow has slackened or has come to a practical standstill, as in the case of a stream emptying into a lake or reservoir, the process of deposit is slow.

All accounts and descriptions of the physical character of the Isthmus of Panama agree that it is volcanic, and the speaker's observations, made while crossing the Isthmus on two different occasions, confirm the view that the general description of the covering strata of Central America, just given, applies also to the Isthmus, possibly in a somewhat less marked degree. A deduction that the Chagres River is no exception, in this respect, to any of the larger Central American rivers which have come under the speaker's close observa-

tion, would seem to be entirely logical. An inspection of the river beds of that region at any appreciable elevation above sea level, where the flood waters are entirely confined by the banks, will fail to reveal evidences of the quantity of fine silt carried by their flood waters, for the reason that nothing but portions of the coarser particles—the sand and gravel—remain, the finer silt particles are carried down stream in suspension, and, if the flood is not large enough to overflow the lower banks, are carried to the sea. Mr. Paschke.

Returning now to the discussion of the tide-level canal, it is to be observed that the proposed dam at Alhajuela will serve most admirably the two-fold purpose of controlling the flood waters and detritus brought down from the upper valley; but, even so, one is confronted by the fact that there exists the tendency to silt up this reservoir in time. And if the control of the Chagres waters depends upon the unimpaired capacity of this reservoir, then its gradual silting up is a serious condition, and must be reckoned with by the designers of the canal works.

From Alhajuela, at the foot of its dam, to Gamboa, where the river strikes the canal, is about 7 miles, according to Mr. Morison's statement. Some tributary streams empty their waters into the Chagres here, and their united waters, by the time they arrive at the canal, will be highly charged with sediment. The proposed receiving basin at this point, mentioned before, can be made a settling basin by enlarging it and deepening it somewhat below the bed of the canal. By periodical dredging, this basin can be kept clean, and in this way the water entering the canal will be freed of all coarser sediment. How much of the finer particles of silt would be deposited in the canal, under the varying conditions of current speed, will be, at this time, for want of reliable data on this subject, purely a matter of conjecture. If the speaker were to venture an opinion, it would be, that the quantity deposited under these conditions would be proportionately insignificant, and insufficient to cause doubt as to the feasibility of the plan.

Again, if the arguments just advanced are applied to the plans for a lock canal, and to Bohio Lake in particular, the conclusion is evident that something must be done to prevent the lake from silting up. Two ways suggest themselves, which, singly or in combination, would effect a partial remedy. One is that the dam proposed to be built at Alhajuela for the tide-level canal would do the same service for the lock canal. The other would be to reserve the part of the lake from Alhajuela to Gamboa for a settling basin, to be kept clean by periodical dredging.

In both cases, though, we are confronted with the ever-existing danger of the final silting up of the lake by the finer material which cannot be precipitated in the settling basin; however, with the ameliorating condition, that the process will be an exceedingly slow one.

Mr. Paschke. To return to the subject of a sea-level canal, it would be interesting indeed if some of the engineers who are members of the Isthmian Canal Commission could or would give some idea regarding the feasibility, and probable cost, of the so-called diversion of the Chagres River from the Alhajuela Reservoir, as proposed by the old de Lesseps Company.

If this is at all feasible, and the cost not so great as to be prohibitive, under the present circumstances, then it would seem that this plan should stand first on the list for consideration. On the other hand, should the plan be found impractical, then, certainly, the plan for a tide-level canal, as outlined by Mr. Morison, deserves serious consideration by the Commission.

Mr. Harrison. C. L. HARRISON, M. Am. Soc. C. E.—The question whether the canal across the Isthmus of Panama should be a sea-level canal, with only tide locks, or a high-level canal, with a number of locks to reach the summit-level, has been a subject of discussion ever since the project was first proposed. The author has presented some of the difficulties involved in constructing a sea-level canal, but there are still others which can be inferred, but may be more specifically mentioned. If the Chagres River is taken into the canal at or near Obispo, then the canal from this point to Colon must be large enough to take the flood volume of the river at Obispo, and, in addition thereto, all the tributary streams between that point and Gatun.

Assuming that the depth is 35 ft., bottom width, 400 ft., with side slopes of 2 to 1, and that the discharge of the river is 100 000 cu. ft. per second; then, in the canal from Obispo to Colon there would be a surface slope of from 12 to 14 ft., and a mean velocity of more than 4 miles per hour, and perhaps a maximum velocity of 6 miles per hour, in parts of the canal. If this flood volume were to be of frequent occurrence or long duration, it might be advisable to make a larger channel and thus reduce the slope and the velocity of the water in the canal. But there is another phase of the subject which must be considered, *viz.*, sedimentation.

A channel of the foregoing dimensions would have, at low water, a cross-section of 17 450 sq. ft. If the discharge were 17 450 cu. ft. per second, then the mean velocity would be 1 ft. per second. At such a velocity the very fine particles of material suspended in the water would settle to the bottom of the canal, and sand would be deposited when the discharge was 50 000 cu. ft. per second. It is probable that a greater discharge than this would carry the suspended matter out into the bay at Colon, and, in addition, scour out some of the deposit which had been made at lower stages of the river. The net result of this would be that nearly all the sediment carried by the Chagres River would have to be dredged out of the canal between Obispo and Colon, or, out of the Bay of Limon at Colon, which would make the cost of maintenance very great.

Mr. Harrison.

The author estimates that "the time in which the discharge at Gamboa would exceed 35 000 cu. ft. per second, or that at Bohio 50 000 cu. ft. per second, would probably not be more than ten days in twenty years." This would mean that there would be some sedimentation in the canal at practically all times; but there are no data to determine the quantity of suspended matter carried in the water or the quantity of sand and gravel moved along the bed of the river by the force of the current. At low and medium stages of the Chagres the water is not nearly as muddy as the Mississippi River above St. Louis, and carries less sediment than the Hudson River above Troy. The speaker has not observed the condition of the Chagres at flood times. Whatever this quantity may be, it is certain that a large part of it would have to be removed from the channel by dredging. This is by no means a difficult thing to do, but it is an item of cost for maintaining the channel.

In the sea-level canal it would also be necessary to provide some special method of taking into the canal all the streams from Gatun to Obispo. Much the largest of these is the Chagres at a point near Gamboa. The flood discharge at this point may vary for different years from 30 000 to 100 000 cu. ft. per second, and it must be conducted from the river, which is about 75 ft. higher than the bottom of the canal, into the canal in such a way as not to produce cross-currents which would impede navigation or erode the banks. This would require the construction of a dam across the river, together with an apron down to about the level of the bottom of the canal, and then the excavation of a new channel from this point to the river, on an alignment that would cause it to enter the canal in a direction nearly parallel to it. If this dam and the channel leading from it to the canal were not built, then the slope of the bed of the Chagres would be readjusted for miles up stream, and all material eroded in this readjustment would be deposited in the canal and would have to be removed by dredging.

These structures, for controlling a flood volume of 100 000 cu. ft. per second, would be very expensive. The cost would depend on the character of the foundations to be had and the kind of structure to be built, and also upon the distance the dam would be located up stream from the canal. The data are not at hand for designing these structures and estimating their cost, but it is certain to be a large item. Similar provision must be made for taking into the canal all the streams between Obispo and Gatun, but they are small compared with the Chagres. It may be that the author has included these two items in his estimated cost for a sea-level canal; but if he has not, then they may properly be added. Independent channels for the canal and the river would avoid these difficulties, but, unfortunately, no safe location for such a river channel has yet been found that could be constructed at a reasonable cost.

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From a personal study of the situation, the speaker believes that the summit-level, as proposed by the author and the Isthmian Canal Commission, with the long spillway at Gigante, is the best solution of the problem. It makes the control of the much-dreaded Chagres both easy and certain.

In the author's estimate of cost, 20% is added for engineering, policing, sanitation, and all other expenses not included in the unit prices for the various classes of work. This may seem excessive to those not familiar with the climatic conditions and the work to be done. The canal is located in a tropical country, which is hot for twelve months in the year and wet for from eight to nine months. Exposure to the night air or the midday sun is almost certain to produce sickness in the unacclimated peoples of the North, from which all the technical talent must be secured. In this climate, work and all other things must be done in moderation. It will require twice as large an engineering force as similar work would require in this country. The water supply and sanitation must be provided and maintained, which will be an item of considerable cost. The brush and timber must be cut and burned on the entire area of Lake Bohio, which is about 40 sq. miles. Should this not be done, the dead timber would float in the lake, impede navigation and interfere materially with the operation of the locks. The allowance of 20% seems to be too small, rather than too large.

In the first paragraph on page 43,* the author has outlined briefly a most important feature in the "conduct of the work," which, to neglect, is but to invite disaster, great increase in the cost of the whole work, and longer time for its execution.

There are but two seasons known on the Isthmus, the wet season, which is generally from May to January, and the dry season, which is generally from January to May, though in many years either of these seasons may begin earlier or later than the months above mentioned. The domestic water supply during the wet season is collected in tanks from the rain which falls on the roofs of the houses, and this, usually, is pure and always abundant, for it rains every day; but during the dry season the water is obtained from occasional rains and from water which was stored in the tanks during the wet season. The result is that the better class of people has a sufficient supply to last through the dry season, but the laboring class does not, and secures water from the most convenient streams or swamps. The dry season is usually considered much more healthful than the wet season. While on the Isthmus, as Chief Engineer for the Isthmian Canal Commission, the speaker collected health statistics which showed that the sickness and death rate were much greater during the dry season than during the wet season. An analysis of these statistics revealed the

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fact that in the dry season there was less sickness among the better classes of people and more among the poorer classes. This, no doubt, was caused largely by the different water used for domestic purposes during that season, and points to the great importance of having good water at all seasons for everyone. It is equally important to provide efficient sanitation at all times. If a good domestic water supply and proper sanitation are not provided, and an epidemic should break out during the first year of active operations on the Isthmus, it would not only result in great loss of life, but it would be exceedingly difficult and very expensive to secure an adequate force of workmen to complete the construction within the time contemplated.

The author, in the closing sentence of his paper, very forcibly states the sanitary conditions under which he expects the work to be done, and his estimates of cost are evidently based on such conditions.

The Isthmian Canal Commission, in making its estimate of cost, contemplated perfect sanitary and police control. From page 261 of its report, the following is quoted:

"A considerable population has long existed on the Panama route, and it lies on a pathway of comparatively large trade, along which currents of moving people from infected places sometimes converge, thus creating conditions favorable to epidemics."

These conditions may be somewhat worse when a great many laborers are employed in building the canal. From page 262 of this report the following is quoted:

"In order to exercise the rights necessary for the construction of the canal and for its management after completion, the United States should acquire control of a strip of territory from sea to sea sufficient in area for the convenient and efficient accomplishment of those purposes. Measures must also be taken to protect the line from unlawful acts of all kinds, to insure sanitary control, and to render police jurisdiction effective. The strip should be not less than 5 miles wide on each side of the center line of the Canal, or 10 miles in total width."

The treaty made recently between the United States and the Republic of Colombia for the construction of the Panama Canal, gives the United States sanitary and police control over a zone of territory about 3 miles wide on each side of the center line of the canal, or a total width of about 6 miles, which is a material reduction from the 10-mile zone recommended by the Commission. But this restriction is not as objectionable as placing the control of the towns of Colon and Panama, which are within the 6-mile zone, under the joint control of the native and United States authorities. It would be better if the control, during the time of construction were vested solely in the United States. Everyone coming to the Isthmus will pass through one or the other of these ports, and their inhabitants would be the first to be exposed to any contagious or infectious diseases brought to the Isthmus from other countries. It is important that the towns

Mr. Harrison. should be put in the very best possible sanitary condition and kept so during the whole time the work is being done. Enforcement of the regulation for this purpose would be easier under single than under dual control.

Mr. Bunau-Varilla. P. BUNAU-VARILLA, Esq.—In or about the year 1884 the speaker started the first dredge to cut the channel in the Bay of Panama, and at that time it was the opinion of nearly all the people on the Isthmus that every bucketful dredged from that channel would be washed back at once. For that reason Commander Lull, when projecting his line across the Isthmus, threw the entrance of the canal to the east side of the City of Panama in order to avoid the mouth of the Rio Grande, which is the point where the entrance is now located.

The work had been studied diligently by the speaker before he went to the Isthmus, and, on arriving there, he observed two facts which confirmed his opinion that the work would be successful and that the depth of such an entrance could be maintained. First, the entrance to the canal in Panama Bay is perfectly quiet, the little Bay of Panama being in a sheltered position within the larger bay, known as the Gulf of Panama, so that the heavy seas from the great storms from the Pacific do not enter it. The bay is remarkably still. Second, the sedimentation and consequent filling in of the bed of the channel in the bay would be caused by the simultaneous action of currents and waves; the waves put the sand and silt in suspension in the water and the currents transport it, and when an excavation is reached the suspended matter settles. Such a current exists; it flows continuously toward the west, but, owing to the complete and regular flow of water, there is practically no material in suspension.

Six months after the channel had been dredged it was examined by the speaker, who found that the depth in the center had been fully maintained. Although the side slopes were modified, the depth on the axis was fully maintained. This is proof that the work in the bay will be absolutely successful. The channel is already dug for a part of the distance, and ships enter and follow it. This question is not open; it is closed. It is not a question of the future; it is settled.

In relation to the question as to the lock canal and the sea-level canal, the speaker has no more fear of sediment in the latter than he has of sediment in the channel in Panama Bay.

The water of the Chagres does not flow through volcanic ground. The word "volcanic" must not be used. "Volcanic" ground means a ground filled with active volcanoes and which produce rock which is very soft and liable to decay very easily under the influence of the atmosphere. It is true that in a country where there are active volcanoes, the waters of the rivers carry an enormous quantity of sediment. The Isthmus of Panama was formed in remote times, before the human race appeared upon the earth, about the end of the tertiary

or at the beginning of the quaternary period, and at the time these volcanoes were active, they did not eject lava, but that stronger material called basalt. Mr. Bunau-Varilla.

The rocks and clays of Panama are extremely stable, and, as a rule, the waters of the Chagres are pure and clean. Of course, during great floods there is a certain amount of erosion, but, at such times, if the water is received into the canal, there will be, also, an increased current, which will take up the silt washed in and carry it through the canal and out to sea. The speaker has no fear upon that point. Of course, there will be the work of maintenance, but, for a canal of that importance, what is it to take out 500 000 or 1 000 000 cu. m. every year? It is absolutely nothing. In the Suez Canal more than that quantity is taken out, and the Suez Canal has not been a failure, up to this time.

There is another very important point: The idea of M. de Lesseps, that a sea-level canal, which has been so successful at Suez, is the final solution for Panama. A sea-level canal must be made and will be made at Panama. There will be a time when the importance of traffic will justify a passage of the highest class, that is, a sea-level canal. But is it justifiable to wait ten years longer in order to give the world the benefits of that great work? Is it not proper to take the intermediate solution, the lock canal? The lock canal should be constructed now, for that assures an earlier completion of the long expected work. It will give a very satisfactory canal for a number of years. But the time will come when the character of the traffic will be so transformed that it will demand the transformation of the lock canal into a sea-level canal. This can be accomplished without stoppage of navigation, although it will cost much more to finish the canal while it is in operation than to make it prior to such operation.

From all standpoints, the speaker would justify the lock canal now; it will answer admirably the needs of navigation for a limited number of years—perhaps twenty or thirty—but thirty years will not pass before the absolute necessity of a sea-level canal will be seen, and plans for its transformation will be begun. Ten years' earlier opening justifies the less satisfactory form, to be in time transformed into its final shape, the American Bosphorus.

George S. Morison, Past-President, Am. Soc. C. E. (by letter).— Mr. Morison.
Replying to Mr. Meigs' first question, the Chagres is not unlike many rivers in the eastern and southern parts of the United States. It has about the same range between maximum and minimum discharges, and is subject to the same hydraulic laws. There is only one respect in which it differs from them essentially. The rainfall in the Chagres basin is double what it is on our rivers; the result is that the same maximum flood is obtained, from an area of less than 900 sq. miles of drainage basin, which would come from four times this area in the

Mr. Morison. United States. Twice as much rain must be disposed of; this means either a larger flood or a smaller basin; in the smaller basin the flood has less distance to travel. With one-quarter the area of drainage basin, we have one-half the aggregate rainfall with one-half the distance to run off, which means the same maximum discharge but a flood lasting but half as long.

The Chagres, under ordinary conditions, is a clear stream with a fall of from 2 to 4 ft. to the mile. In the upper river there are no signs of silt or other alluvial deposit, but between Alhajuela and Gamboa there is some small amount of bottom land and silt deposit. The erosion of this bottom land in times of flood is apparently the chief source of sediment in the lower river. With the high-level canal plan this silt region will be drowned and this erosion stopped. The amount of sediment which will be brought into Lake Bohio is less than must be expected in any of our Atlantic harbors. With the tide-level canal the danger will continue, but the amount of such erosion can hardly be considered excessive.

With reference to the difference between the elevation of the Chagres in flood times at Gamboa and the bottom of the proposed tide-level canal, anything approaching a vertical drop, if it were possible, would be destructive. Such a drop, however, is impossible. The bed of the Chagres is earth, not rock. If it were rock, this would be the place to build the upper dam. If ever a tide-level canal is built, the broad channel which will carry off the drainage of the Chagres must be extended at least a mile up the valley beyond the canal, and such barriers must be constructed as will retard the flood in the river and thereby reduce its destructive force. No plan has ever been worked up in detail to meet this provision, the tide-level canal being removed from present consideration for the reasons given in the paper.

The estimates made in the paper are adapted from the estimates prepared by the Isthmian Canal Commission and used in reaching its conclusions. The principal savings are in the Bohio Dam, in the reduced amount of excavation in the Culebra Cut and the shallower portions of Lake Bohio, in the reduced excavation on the Pacific level, and dispensing with the diversion channels on the Chagres above Gatun, the Gatun Channel being retained. The cost of the canal itself from Colon to Lake Bohio is slightly increased, the Commission's estimate of the two being as follows:

	Commission's Plan.	Tiger Hill Line.
Atlantic Maritime Level	$19 006 199	$12 184 981
Tiger Hill Level	.....	5 638 874
" " Lock and Spillway	.....	5 024 056
Bohio Locks	11 567 345	9 014 632
	$30 573 544	$31 862 543

The increase of $1 290 000 is more than balanced by a saving of $2 700 000 in the cost of the diversion channels. By removing the canal to the more direct line, the present canal, which is now actually the bed of the Chagres, is left available as a diversion channel, a use to which it is admirably adapted. Mr. Morison.

There are four questions which the writer would like to have discussed at this time:

The first of these is the relative merit, under the circumstances, of the tide-level and the high-level canal, the difference of cost and time being as now estimated. The great difference is the time required for construction, which would be fully ten years longer for the tide-level than for the high-level canal. The tide-level canal could not be without locks. A 20-ft. tide on the Pacific side makes a tide lock necessary. The gates of this tide lock could stand open at certain stages of the tide, so that it would not absolutely limit the length of ships passing through, but with a tide-level canal, the same limiting sizes would exist for the greater part of each day as with a high-level canal. The tide-level canal would be a canal for the whole width of the Isthmus, although a portion of it would be pretty wide. The advantages of the inland lake would be lost. The inland lake makes two short canals with good anchorages and good repairing ground between —this is no small advantage.

The next question is whether it is important to try to reduce the size of the locks below the great lift proposed in the plans of the Commission for the locks at Bohio. By using the third lock at Tiger Hill, as described in the paper, the normal lift of the locks is reduced from 42 to 28 ft. There is not the slightest doubt that a lock with a 42-ft. lift can be made and used, but an injury to such a lock in case of accident would be much more serious than to a smaller lock of less lift. Whether there is any more danger of injury occurring is a point which may be considered. Even with three locks, the time of passing through the eastern canal will be a little less than the time of passing through the western canal. Which is to be preferred, the two locks of 42-ft. lift or the three of 28-ft. lift?

The third question is the water supply for the summit level of the canal. The Chagres River supply is adequate for all but three months of the year. This deficiency can be obtained by drawing water from the lake. It can be obtained by another reservoir above Alhajuela. In the writer's judgment, it is best to postpone the final decision; to build the canal with no provision for this additional water, but, for the first few years it is operated, to allow the depth of water in the canal during the extreme dry season to be reduced, perhaps from 35 to 33 ft., and, ultimately, to provide a reservoir above Alhajuela to make good this deficiency. This would save something in the first cost of construction, and would ultimately give an indefinite supply. Is it right or wrong?

Mr. Morison. The fourth question is whether it is expedient, in a harbor like Panama Bay, with an extreme tide of 20 ft., to construct a channel giving a maximum depth at all stages of tide, at an additional cost of about $5 000 000. The reduction of this channel is one of the items which has reduced this estimate below the Commission's estimate. With a channel 35 ft. below mean tide, a ship requiring 25 ft. could always come in. A ship requiring 35 ft. could come in 18 hours out of the 24. How much is it worth while to pay for this additional 6 hours a day for ships of extreme draft? At high tide, with the channel as described in the paper, the depth would be 45 ft. With a channel 35 ft. deep below low water, it would be 55 ft. There are few harbors with large tides where anything like this has been done.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE PRESERVATION OF MATERIALS OF CONSTRUCTION.

An Informal Discussion.*

By Messrs. William Barclay Parsons, Rudolph P. Miller, George Hill, Oscar Lowinson, Henry B. Seaman, George A. Just, A. Gideon, Franklin Riffle and Edward P. North.

Presented at the Meeting of February 4th, 1903.

William Barclay Parsons, M. Am. Soc. C. E.—Engineers are accustomed to put into structures materials which are expected to remain unimpaired for a great many years, but are obliged to take a great deal on faith; therefore it is especially interesting to examine any material whose age can be thoroughly authenticated, and whose state of soundness or decay can be ascertained accurately. Mr. Parsons.

Last autumn, while inspecting the subway construction of the Metropolitan Railway in Paris, the speaker was shown some timbers which had formed part of the foundations of an old building erected in the fourteenth century; and the chief engineer, Mr. M. F. Bienvenue, has very kindly sent some pieces of the piles and the timber grillage, which now, on his behalf, and in his name, the speaker takes great pleasure in presenting to the Society.

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV, p. 71). Communications on this subject received prior to April 24th, 1903, will be published subsequently.

Mr. Parsons. The following is a translation of the letter accompanying these specimens:

On October 5th, 1902, while excavating the trenches under the Place de la République, for that part of the Chemin de Fer Metropolitain between Courcelles and Menilmontant, there was discovered a great quantity of oak piling supporting an oak platform.

The piles were from 1.50 to 2.00 m. in length, and from 20 to 25 cm. in diameter. The lower part of each was sharpened to a square point, but bore no traces of iron banding or of crushing. The width of the platform timbers varied from 50 to 70 cm., and their thickness from 10 to 15 cm.

This wood, which was a true pile foundation, has been identified as composing part of the foundations of the old "Porte du Temple," having formed part of the wall of Paris during the reign of Charles V (1364–1380). The preservation of the wood is perfect, notwithstanding the fact that it has been in place since the fourteenth century.

The lower part of the piles was embedded in a green argillaceous sand, while the upper part was in a blackish, marshy soil, filled with sulphurous and ammoniacal gases.

The lower part of the platform was about at elevation 29.00 at the point where it was uncovered, the elevation of the surface of the ground at the Place de la République being about 37.00.*

On top of the specimen of the pile may be seen fragments of the cement or lime probably used to level out under the grillage. When the wood was received, a few weeks ago, it was intact, but, by lying in the speaker's office, the heat has produced certain checks and cracks. The pile is in a perfect state of preservation, the wood is soft—not hardened at all—and resembles a piece of wood which has been in the ground but a short time.

The two specimens of the grillage on top of the piles are also checked, owing to the office heat, but, on both pieces—the larger piece especially—remnants of the bark may be seen, showing that even the bark is still intact.

It is interesting to recall that these pieces of wood were put in the ground at a period before the discovery of America equal in length to that period which has elapsed since the Declaration of Independence.

As indicative of the fact, however, that French soil is not the only kind which will preserve wood, sections of the first water pipes laid in the City of New York, by Aaron Burr's Company, about the year 1800, have been found recently in Centre Street and the adjoining streets, by the contractors for the Rapid Transit Commissioners. These are not as old as the French wood, but, nevertheless, they are sufficiently venerable, as they have now passed into their second century. Some of the pipes are quite decayed where they have been buried in dry sand, but where there has been moisture in the sand, the wood is still sound.

* The original letter of Mr. Bienvenue, together with the samples of wood, and a plan of the exact location of the old foundation, are on file in the Library.

Mr. Miller.

RUDOLPH P. MILLER, Assoc. M. Am. Soc. C. E.—Considerable interest has been aroused by the demolition of a modern steel-skeleton building in New York City. Many varying expressions as to what would be revealed when the steelwork should be exposed, especially as to its state of preservation, led the Superintendent of Buildings for the Borough of Manhattan to have the building examined carefully during its demolition. Photographs and notes have been taken since the work of demolition started about six weeks ago. The building has not yet been taken down completely, and a full report on the matter is not yet prepared. The photographs, unfortunately, do not show the condition of the material, it being difficult and practically impossible to distinguish on the pictures between rust and discolorations due to the adhesion of particles of the fire-proof coverings, yet they can serve conveniently the purpose of illustrating some of the facts to be noted.

The building was situated on the north side of Forty-second Street, running from Broadway to Seventh Avenue, and was known, variously, as the Thorley Building and the Pabst Building.

It was erected about four years ago, having been started in October, 1898, and completed about a year later.

The steelwork was put in during the months of December, January, February and March. The structure was about 25 ft. deep, of an average length of about 54 ft., and was nine stories high, or about 108 ft. The foundations were on rock.

The construction consisted of a frame of Z-bar columns, with beams and girders carrying the floors and walls at each story. The walls were of brick, except those of the second story, which were of limestone, the first story having an iron front.

The steelwork when delivered at the site had received one coat of carbon paint. It was put up as fast as delivered, and was followed very quickly by the masonry. In some portions of the work the masons were so close behind the erectors that part of the framework probably never received a second coat of paint.

It is interesting to note that the steelwork in the fourth, fifth and sixth stories showed more rust than that in the stories either above or below them.

The interior columns, for the most part, were enclosed in hollow terra cotta blocks, but by no means always solidly. Along the webs of the Z-bars, at right angles to the web of the columns, the contact between the steel and the fire-proof covering was generally complete. On the other sides of the columns, however, the terra cotta blocks were often placed spanning the space between the Z-bars, leaving a void between the fire-proofing and the main web of the column. The steelwork was in equally good condition on all sides of the columns. These columns showed little patches of rust here and

Mr. Miller. there, but none that could not be explained by some cause at work before the steel was put in place. For instance, the rust may have set in under the mill scale before the columns were painted or set, not being visible from the outside, as the mill scale is a non-corrosive oxide of iron. There was in no case a general or extended rusting of any steel member. The points where rust showed in the columns most generally were the rivet heads and the connections.

The connections were the parts most affected by rust. The worst example of corrosion in the building, thus far, is illustrated in Fig 1, Plate XXX. In this case, practically the entire inside of the splice plates, where they show black on the photograph, was rusted, and the faces of the connections that were in contact were rusted. The speaker has no doubt that, in setting one column above another, considerable force was used, and the friction between the parts was sufficient to rub off the shop coat of paint. The heads of the field rivets were the places where rust was oftenest found, yet in no case, except in that illustrated, was the rust of a thickness that could be measured by ordinary means. In this case the thickness was from 0.02 to 0.025 in.

The wall columns were encased in brickwork, 8 ins. thick on the outside and 4 ins. thick on the inside, the inside 4 ins. being what is known as furring bricks. In some of these columns there were indications of rust in layers, as shown in Fig. 2, Plate XXX. The steel was free from rust where the cement mortar came in contact with it, but between such points it appears as though the porous brick permitted the entrance of sufficient moisture to start rust; but, again, in no measurable quantity. This is in accord with observations made in a number of other instances where alterations in a building have exposed steel columns.

The floor beams and girders throughout the interior of the building, except the top flanges, were encased in the cinder concrete forming the floor arches of the building. The concrete was made up in the ordinary proportions for that form of construction (that is, 1 part cement, 2 parts sand and 5 parts cinders), and was a fair sample of cinder concrete as generally used in building construction in New York City. Yet the steelwork thus protected was remarkably free from rust. Where there was any, it was in very small patches, more generally on the rivet heads, and it was probably there before the floor arches were placed.

Practically the only place where any rust was shown was on the webs of the channels forming the frame for the stair-well and elevator shaft, and then it was on the shaft side, where it was not covered with some protective material other than paint.

The wall girders, encased in brickwork on the outside, showed signs of rust along the edges of the flanges toward the outside of the building. This was more especially true of those in the northerly

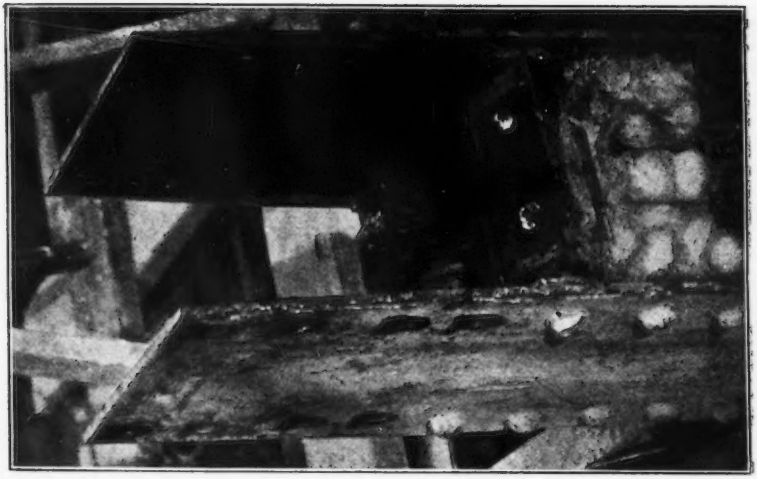


FIG. 1.—CORRODED SPLICE PLATES.

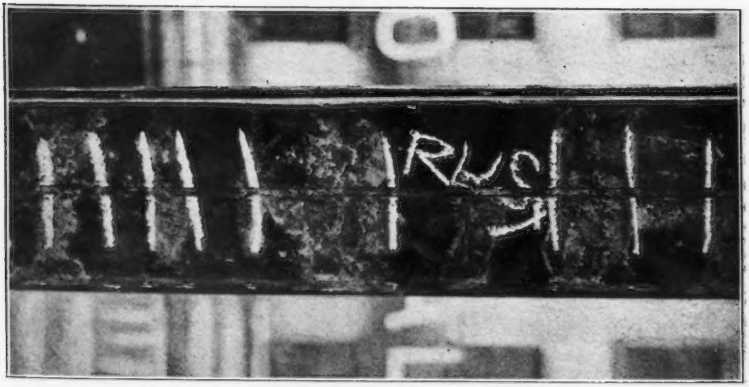


FIG. 2.—RUST SHOWING ON STEELWORK WHERE CEMENT WAS NOT IN CONTACT WITH STEEL.

wall, which, for most of its height, was exposed to the weather. The adjoining building to the north was of four stories. The flanges of these wall girders came within about 2 or 3 ins. of the outside of the wall of the building. Mr. Miller.

A built-up girder, in the westerly wall, at the second-story floor level, shows two patches of rust on the web of the girder. No explanation has been found for these patches of rust, which are exceptional. The sides of the girders were thoroughly encased. It may be remarked that the present indications are that the steelwork yet to be removed from this building, in the basement and cellar stories, will show considerably more rust than any taken out of the upper part of the building. It should be noted that the steelwork was erected during very bad weather, and the location was a particularly damp one. On one or two occasions the work had to be stopped on account of snow storms or rain.

The concrete of the floor filling was segmental in form, and was supported by temporary centering, consisting of $\frac{1}{2}$-in. round bars spaced about 9 ins. apart, which stiffened the wire netting. This centering was rusted throughout the building—generally, however, only on the side exposed—and the rust is not more than would develop during the drying out of such a floor construction. This floor was hidden and covered over by a flat ceiling, secured to the lower flanges of the beams. The rusting evidently did not continue after the floors had dried out and the ceiling had been put in place.

The boiler stack of the building was of $\frac{5}{16}$ and $\frac{1}{4}$-in. sheet-steel, and was covered with asbestos.

The stack was completely covered with rust, the asbestos covering evidently offering no protection, although the galvanized wire woven into the asbestos covering was as bright as the day it was put in.

The expanded metal used in the partitions was very badly rusted throughout the building. This may have been rusted when put in, for such material is generally sent to a job in bundles, and lies about, exposed to the weather, for some time before being put in place; but the material of the partitions, which was a patent plaster, evidently did not arrest the corrosion, but probably increased it.

One 6-in. floor beam, shown in Fig. 1, Plate XXXI, was rusted badly for an area of, perhaps, 1 sq. ft.; but all the indications are that this beam, over this particular spot, was never painted. Evidently, the beam was marked at this place at the mills before being painted, and, when painted, this spot was not touched, in order not to obliterate the marks.

All steelwork erected in New York City is supposed to receive a coat of paint after being set, but this is not always done, for several reasons—sometimes to save the expense, which the speaker is sure was not the case in this instance; often because of the untrustworthiness of

Mr. Miller. the workmen, who shirk those parts which are difficult of access; again, when the masons are following close behind the steel erectors, they will not wait for the painting. The tops of beams and girders do not often get the second coat of paint because the erectors in climbing over the steelwork are more likely to slip on the freshly painted surfaces. Fresh paint in the connections is likely to spurt out during riveting, and therefore connections are often neglected.

To show how the beams come to the site unpainted sometimes, a photograph of some steelwork delivered for a new building in New York City is shown in Fig. 2, Plate XXXI.

Where the shop marks are placed on the beams, they have not been painted over at all, and, in this instance, the beams have already rusted at such places. The same beams also show indications of rust along the connections, as indicated by the chalk marks—not much, to be sure—but whether or not this incipient corrosion will continue is an open question. It is very doubtful that the rust will be scraped off before the next coat of paint is put on, and if not, it is doubtful whether the paint will be of much use. It is difficult, too, to follow the painting during erection. To meet this difficulty, some architects specify that the steel shall be painted with red lead before delivery, and with carbon paint during construction. They can then tell by the color whether or not the second coat is complete. All unpainted steel that came out of this building, whether enclosed or not, was rusted.

The speaker has been describing the places where rust was found, but it should be stated that the quantity of rust in this building was small. Most of the cases were found in the fourth and fifth stories, where the rust spots were most frequent. The steel frame, generally, was remarkably clean and free from rust. The conclusions to which these studies lead simply corroborate those of which engineers have already felt fully convinced—that paint, applied properly, is a protection to steel, at least for a certain time; that cement mortar is a very efficient protection for steel, and that ordinary cinder concrete also serves this purpose quite satisfactorily.

Mr. Hill. George Hill, M. Am. Soc. C. E.—The speaker has thought of this subject under certain headings:

First.—The preservation of materials of construction against atmospheric deterioration, a branch which can be dismissed, because, in general, the use of such materials as will be safe against the action of frost or the elements is always attempted.

Second.—The preservation from injury due to soot or dirt from the atmosphere, a branch of the subject with which the speaker has had very little experience. Many handsome buildings are spoiled by reason of the soot, and attempts have been made, by the use of glaze on terra cotta, and by various forms of materials supposed to be impervious, or by paraffine compounds applied to the exposed surfaces, to prevent this, and it is claimed that this has been done successfully.



FIG. 1.—SIX-INCH FLOOR BEAM.

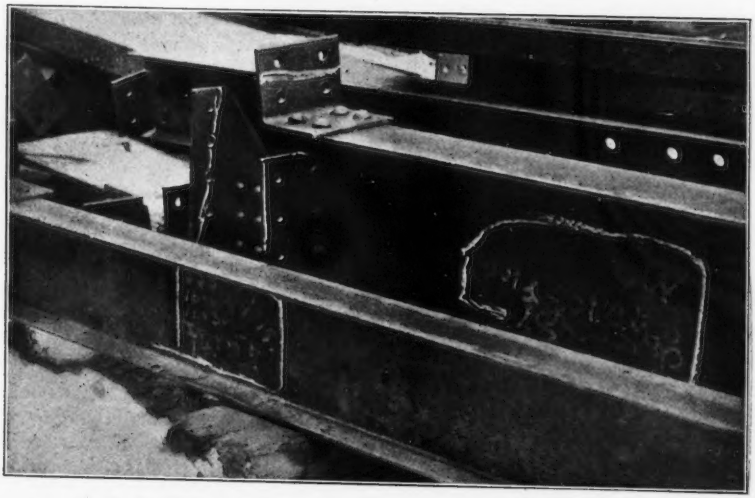


FIG. 2.—STEELWORK; PAINTED, EXCEPT WHERE SHOP MARKS ARE SHOWN.

Third.—Protection from dampness striking through. In that particular line, the speaker has had some experience with certain walls made of patent plaster, Portland cement and sand, 2 ins. in thickness, and used as external walls of manufacturing buildings, coated with some of the compounds which are on the market, and has found that they were efficient. He has also had experience with brick walls, coated on the inside with similar compounds, and has found that the dampness was excluded. In general, it may be said that there are certainly half a dozen different compounds, which can be obtained at a reasonable cost, which will protect buildings from deterioration through the striking in or the transmission of dampness. Mr. Hill.

Fourth.—When it comes to the preservation of metallic structures, the speaker thinks that this discussion should be in the nature of an experience meeting, and, in general, the failures rather than the successes should be described. For instance, during the last five years the speaker has erected quite a number of buildings with external curtain walls, composed of hard plaster, Portland cement and sand in equal parts, the scratch coat being applied to uncoated metallic lath, making the thickness of the scratch coat about 1 in., then a surfacing coat of Portland cement, ½ in. thick, was applied on each side, making the curtain walls a total thickness of about 2 ins. These buildings have been put up at various times, the latest one being about four years old. All are in first-class condition at present, with the exception of one.

This building is one of four, and was erected in the winter. The scratch coat was alternately frozen and thawed several times. Two years after the building was finished it was found that the outer surfacing of cement was cracking and falling off. Sheets having an area of 8 or 10 sq. ft. came off, leaving the scratch coat bare. This was left alone, and the deterioration or destruction of this wall has been going on for about two years. The entire wall now is in rather bad shape, and it is proposed to put it in good order. In every case there was a separation between the finishing coat and the scratch coat, and, in general, the wire lath, where it was on the surface of the scratch coat, or where the scratch coat came very close to the surface of the lath, was very badly rusted; but, in places, this was little more than a discoloration. In other places, the wire lath, while rusted, was probably in exactly the same condition as when the plaster was first applied to it; because sometimes several days elapsed after the bare lath was erected before it could be covered, and there is no doubt that during that time it rusted.

The adjoining building, erected in the following spring, is in absolutely perfect order to-day, and all the other buildings are in equally good condition, so that this failure was due to the alternate thawing and freezing of the scratch coat, which prevented the forma-

Mr. Hill. tion of a proper bond between it and the surfacing coat. It may be that the surfacing coat, which was of undue thickness, reaching in places as much as 1 in., was too thick, and that that was responsible for a small part of the trouble.

Fifth.—In the protection from oxidation of such a metallic structure as Mr. Miller has described, the speaker has observed a few cases where the paint on the steel has been protected with metal lath and Portland cement, and in every case has found that it afforded a sufficient protection.

In the matter of painting, although personally interested in one paint concern and very well satisfied as an individual with its product for forming a preservative coating, it is the speaker's belief that there are several paints or preservative coatings for metallic structures, to be had at the present time, which will give satisfactory surfaces when applied properly; in fact, the intelligent application of the covering, in accordance with the manufacturer's directions, has almost as much to do with a satisfactory service as the composition of the paint.

Sixth.—In protection against fire the speaker had one experience which is instructive. The building was of the ordinary steel-skeleton type, and a fire occurred on the fifth floor, the heat being sufficiently intense to soften the steel steam-pipe risers, so that the deflection in some cases was as much as 6 ins. It also melted the brass air-valves on the radiators. The flames passing out of the windows melted the solder in the copper cornice, five stories above. The Fire Department was able to erect a water-tower and direct the stream from it horizontally into the building, and the fire was put out by drowning; that is, the entire floor was filled until the water flowed out over the window sills. This stream struck several of the columns, all of which were wrapped with wire lath and plastered with Portland cement and sand, with a thickness of about $\frac{3}{4}$ in., on which the white coating was applied. This covering resisted the effects of the heat and the hose stream in every case except one, where a portion of the covering, about 18 ins. long and 12 ins. wide, was torn off; but, evidently, that did not occur until the fire was practically out, because the paint on the column—the building had been erected about a year and a half—was intact and not blistered by the heat.

Some years ago the speaker made a series of experiments for the representatives of the System Mélan, using stone concrete with Portland cement surrounding T-bars of steel bent into the segment of an arch. He found that in every case, although the steel sections had been exposed to the weather for from 60 to 90 days unprotected, wherever the concrete had been in contact with the steel, no rust showed at all. The steel was not painted, and showed bright; but wherever there were voids in the concrete, due to the use of rather dry concrete with a stone aggregate, rust had set in.

Mr. Hill.

In the tests made, for the expanded metal companies, in Long Island City, the slabs were generally made of very wet cinder concrete, and, during December and January, for from 30 to 45 days, were exposed to atmospheric conditions. The steel which was embedded in the cinder concrete, or in the gravel concrete, as the case might be, was absolutely unchanged after the destruction of the slabs. A chunk of cinder concrete, in which expanded metal was embedded, and which, when it came to the speaker, was reputed to have been exposed to atmospheric conditions for five years, was kept for about a year on his window sill, where it was exposed to atmospheric conditions until the expanded metal which projected was rusted about half off. It was then split, and it was found that the expanded metal embedded in the concrete was clean and bright.

Nearly two years ago the speaker lined a very bad shaft, for the Lackawanna Railroad Company, at Scranton, Pa., with cinder concrete and expanded metal. The shaft was through quicksand, about 60 ft. to rock, and was notorious for its bad character. The wood lining put in previously had been in place about six years, and was generally rotted through. It was necessary to replace it either with wood or masonry. Expanded metal was used, with Atlas Portland cement and furnace cinders taken from the ash pile at the power-house operating the breaker in connection with the mine. The cinders were taken from this pile without any selection, and without screening. A few days ago an examination of the lining was made, and it was found to be in as good condition as when put in. The condition of the expanded metal could not be ascertained very well, but if there had been any deterioration, if the Portland cement and the cinder concrete had not been an absolute protection to the iron, the character of the water surrounding that shaft and constantly flowing through it was such that it would have eaten up every portion of the iron within a year. It is believed that under such conditions the cinder concrete acts as an absolute protection to the steel.

It seems to the speaker that it would be of great interest, and a great benefit to the Society, if the Special Committee on Uniform Tests of Cement should have its scope extended, so that an investigation could be made of the effect of neat Portland cement, Portland cement used with various aggregates and Portland cement adulterated with various lime or patent materials, in respect to the preservation of steel. The Society can certainly do very useful work along this line, and if such tests were extended to cover the use of cement in the way in which it is actually used, so that some analogy could be drawn between the test as made and the use to which the cement is put, its utility would be increased still further.

Among the practical builders in New York City, there are a good many curious notions. Some of them have told the speaker, with great

Mr. Hill. seriousness, that it was very dangerous to embed a steel grillage in neat Portland cement; that the cement burned the steel, and that this effect was entirely overcome if a little lime were added. Others have said that it was not possible to grout a cast-iron base with pure Portland cement, because it invariably swelled, and so on, through the whole list. Everyone who has done any work has undoubtedly heard the various peculiar notions of the "practical" men, those who have a certain amount of hand knowledge, and who do not use their heads in connection with it.

As far as the speaker's observation goes, steel which has been properly embedded in concrete remains absolutely unimpaired and perfect in its condition. The effect of painting or oiling the steel before the application of concrete does not seem to be injurious, in view of the fact that the steel cannot always be covered immediately. In the protection of relatively large sections—with the exception, perhaps, of the steel which goes into the grillages, where a most perfect covering is desirable—it would be well to give the steel one or two coats of paint; but, for the grillages, especial care should be taken to cover them thoroughly, and, in such cases, as intimate a contact as possible should be secured between the concrete and steel.

In the application of steel for the re-enforcement of concrete, the fundamental principles are that the steel should be used in small sections and of such form that it will retain its position in the mass of concrete by reason of the form rather than by reason of the adhesion between the concrete and the steel; so that a preservative coating would have only a small influence on the strength of the combination; but, as the preservative coating is expensive, and makes the steel unpleasant to handle, and as the steel can always be embedded in the concrete promptly and thus preserved from initial rusting, the speaker thinks it well that the smaller sections should not be coated.

In the mixing of concrete, the usual practice, or, at least, the practice that the speaker was taught, is wrong. It is very much easier to make concrete too dry than too wet. The concrete in the Pabst Building, described by Mr. Miller, was mixed so wet as to be really muck, and was deposited practically without tamping.

In the last few years the speaker has used a great many thousands of barrels of Portland cement in concrete, almost all of which has been deposited without tamping, and all of it so wet that the natural slope was about 30° from the horizontal. His theory of the matter is that the very fine portions of the cement are washed down in that way, and coat the steel perfectly and fully, and that the excess of water renders any extensive tamping unnecessary and thereby effects a material economy in the cost of making and depositing the concrete. The speaker's observation of a great deal of concrete deposited, usually in thin sections—sections of from 4 to 8 ins. in thickness—is that

this excess of moisture does not result in a porous concrete, nor does any noticeable shrinkage result; but that, on the contrary, it saves time. Mr. Hill.

One serious danger in concrete deposited during warm weather is that of an insufficient quantity of water, and a consequent drying of the concrete. The following experience is an illustration of this danger. Some twelve years ago, when the speaker was designing engineer for a firm of architects, it was decided that a certain windmill tower, with a heavy stone base, should contain a steel tank 50 ft. high and 14 ft. in diameter, the stone base being about 25 ft. in diameter. This stone base was to enclose a small engine-room, so that the tower had to be supported directly over the engine-room. A steel angle-iron skewback was put in and a Guastavino arch formed. Then, to make a leveling for the tower, a contract was made with a certain party to fill the haunches, to a minimum thickness of 1 ft. over the crown, with Portland cement and broken-stone concrete. The men were careful to do what they called a good job. The concrete was mixed very dry—not quite as moist as brown sugar. It was thoroughly well tamped, and then exposed to the sun and wind, and dried out very quickly. The tower was put on before the speaker had an opportunity to inspect it. That concrete was just about as good as so much dried mud, and all of it had to be scraped out with shovels, with the occasional assistance of a pick and crowbar.

William Barclay Parsons, M. Am. Soc. C. E.—The preservative effect of cement mortar on steel has been noticed by the speaker in the case of some steel beams taken out of the sidewalk vault of a building on Fourth Avenue, in New York City. These beams were put in place in 1880 or 1881, so that they are now about twenty-two years old. They carried brick arches for most of their length, but the outer or curb ends were embedded in rubble masonry. Mr. Parsons.

Above the jack arches a space of 2 or 3 ins. was filled with ashes, on top of which the sidewalk was laid.

The beams are in very good condition, except at the ends near the curb, and where the rubble masonry had been cracked by the impact of wheels against the curb, thus permitting water to percolate and attack the steel.

On comparing the part which had been embedded in the masonry with that part which had carried the arches, it was noted that the latter, although it had never been painted, was practically free from rust.

The speaker would like to ask the members to give their opinions as to whether steel should be painted before being embedded in masonry, or whether it is better to let the cement come into direct contact with the fresh metal. This is an important question, because a great deal of steel is now being embedded in concrete.

Mr. Lowinson.

OSCAR LOWINSON, Assoc. M. Am. Soc. C. E.—In reference to the protection of metallic surfaces, especially those exposed to moisture, the subject that has troubled most engineers has been the question of what is known as the progressive oxidation of those surfaces; for the life of a structure is really dependent upon whether oxidation which started at any period in the life of that metal will continue.

Now, in connection with structural steel, it has been the speaker's custom to try to get all the rust off the metal before painting it. He has made examinations of metal painted with various kinds of paints, and found that oxidation frequently continued and caused increase in rust, very slightly perceptible for a while, but after several years becoming scaly and throwing off the paint. The proper protection of that metal by paint, he thinks, is necessary, especially when it is to be embedded in masonry, or in any case where that metal will be exposed to moisture, because iron or steel will only rust when oxygen, together with moisture and carbonic acid, is present.

It would be advisable at all times to make sure to have a protective coating of paint of some kind in addition to the pure cement. It is undoubtedly true that Portland cement is a good protective coating for steel, but it is also true that it is impossible to protect steel with a wash of Portland cement, for the reason that it will not adhere to the steel.

One question that has been touched slightly by Mr. Hill is occupying the attention of many architects at present, and, that is the protection of walls in order to prevent the attacks of the elements, principally the penetration of moisture. In fire-proof buildings, an effort is made to do away with furring, because it is found that in most cases a furring course is not sufficient to prevent moisture from coming through the wall and destroying the plaster.

There are on the market at the present time a score of what are known as damp-resisting compounds, and which are supposed to serve as moisture repellants. Most of these are of no value whatever for this purpose.

These damp-resisting compounds may be divided into two classes: Those which are put on the inner surface of an exposed wall, the plaster being applied directly on the paint; and those which are applied on the exterior surface of a wall, over which is put a coat of good paint, for a finishing surface. Of the first variety, the only correct kind is a hydrocarbon compound, which should be free from tar, pitch and oil, and should also be proof against alkali. It should be a sticky or non-drying compound, to which cement mortar or plaster will adhere permanently, and which water or moisture cannot penetrate.

The second variety, for exterior use, is a chemical compound, of the nature of a quick-setting, very finely divided, hydraulic cement, applied as a paint, which, when partially set, cannot wash off in a rain

storm, and which will take linseed-oil paint without peeling. An ordinary cement wash will absorb moisture, and disintegrate; not only this, but it is also common experience that linseed-oil paint will not adhere to a cement surface. The reason is that, in the hydration of cement, Ca_2O is set free, and, with linseed oil, forms a lime soap, which will wash off. Mr. Lowinson.

The theory of the setting of cement, largely accepted, is that an excess of moisture does not ordinarily injure it, but the cement in its setting has the inherent ability of rejecting all the unnecessary water in order to permit it to set properly and attain its hardness.

A sufficiently thick layer of cement mortar on the outside of a brick wall forms an excellent water resistant if it has time to set before moisture or frost attack it. There are two or three materials on the market at present, which the speaker believes are made of Portland cement, with mixtures of either caustic lime or oil, for the purpose of preventing moisture from getting into walls.

In building work it is a very serious problem to protect plaster properly from attacks of moisture, and a great deal of time must be devoted to the study of the subject before enough is known about the resisting ability of these materials, to determine whether or not they are being used properly.

HENRY B. SEAMAN, M. Am. Soc. C. E.—In speaking of the desirability of painting iron before embedding it in concrete, we should not lose sight of the fact that the present tendency is toward the use of steel-concrete construction; and, in that case, the steel should not be painted. The theory of the strength of this form of construction depends upon the adhesion of the concrete to the steel, and a coat of paint will prevent this adhesion. In this case the twisting or roughness of the rods is all that prevents them from slipping. The lack of adhesion of concrete to painted iron was illustrated recently where a portion of the side-wall of the New York Subway was moved bodily off its foundation, to make room for an extra track. The side-wall was composed of I-beams, with concrete arches between, and, when it was moved from the foundation support, portions of the concrete arches slid down the I-beams as though they had been lubricated. Mr. Seaman.

The requirement that steel should be bright and clean before being painted may be carried to unreasonable extremes. If paint keeps the oxygen from the iron, it will prevent further corrosion, even though slightly rusted when the paint is applied. It is necessary, however, to clean the iron of all scale, whether of rust or other material, which might cause the paint to flake off. A first coat of paint would probably adhere better to iron with a dull surface, than if the iron were bright.

A number of years ago it was generally considered that the Phœnix column would rust inside; and as evidence of this condition the rusty

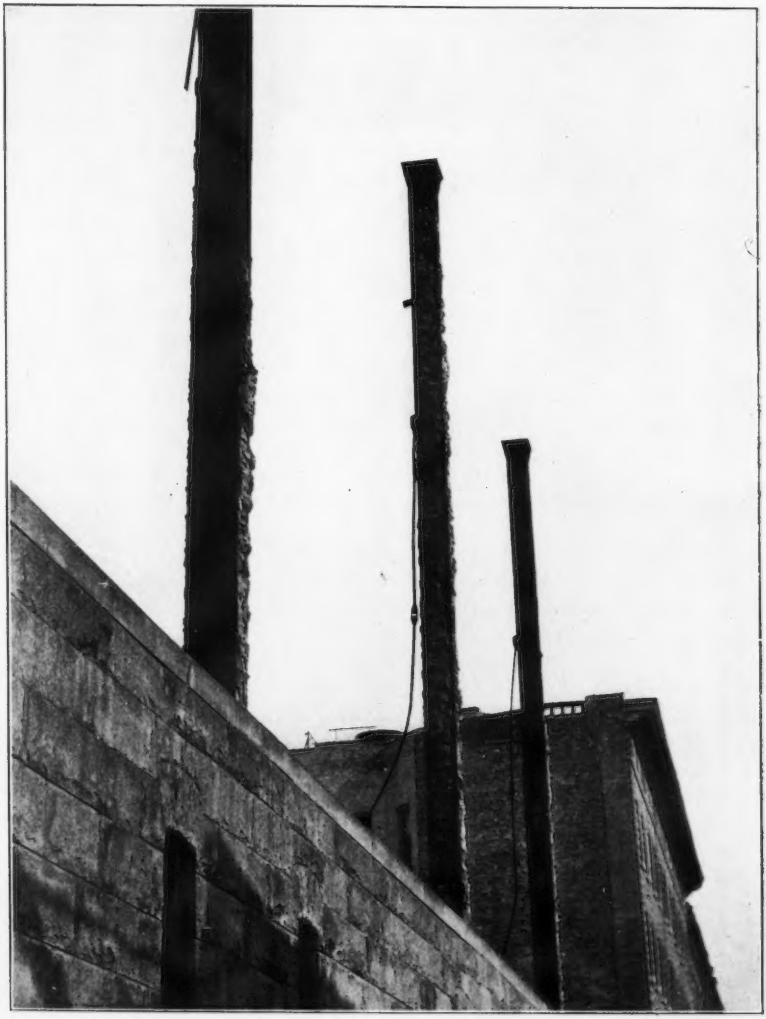
Mr. Seaman. drain holes in the under side of horizontal chords of truss bridges were cited. In 1891, an examination of one of the columns of the Kinzua Viaduct was made, in order to ascertain the condition of its inside surface. The viaduct had been in service about nine years. One of the highest bents was selected, and a piece of iron, about 2 ins. in diameter, was cut from the underside of an inclined column, at a distance of about 2 ft. from the base. As the cutting was completed, the hard oxide-of-iron paint inside the column was broken along the edge of the cut and showed a clean bright surface on the iron. This demonstration needed no further argument, and indicated that iron would last indefinitely if kept from air and moisture. This fact would seem to be equally reassuring as to the life of "iron-skeleton" buildings constructed in recent years.

It is interesting to note the difference of opinion among various engineers as to the quantity of water desirable in mixing concrete. Some specifications require "water in such quantity that the concrete will not flush after being rammed," which may aid quick-setting, but can be fulfilled by a mixture almost dry. On the other hand, there is the requirement that it shall be floated, as mentioned by Mr. Hill, though some engineers consider that this would "drown" the cement. A medium between these two extremes is, perhaps, preferable, or, as General Gillmore used to say: "So much water shall be used as will just flush the surface of the concrete after thorough ramming." It is important, of course, that the concrete should be first thoroughly rammed solid against the steel surfaces.

Mr. Just. GEORGE A. JUST, M. Am. Soc. C. E.—In so far as the question under discussion relates to the deterioration of structural steel when embedded in masonry, Mr. Miller's careful presentation of the conditions revealed by the demolition of the so-called "Pabst" Building is very interesting.

He is in error on one point, however. The structural frame did receive two coats of black (carbon) paint, one at the shops and a second coat during erection. This last coat was probably not applied with any greater care than is usual, under the rapid rate of construction which has now become characteristic for this class of buildings in New York City and elsewhere.

The limited life of skeleton buildings, by the early disintegration of the frames, because of their inaccessibility in the finished structure, which has been predicted so universally by laymen, is based on no knowledge or experience. Failure in this type is rather to be looked for from faulty design of frame or footings. It is gratifying, therefore, that the opportunity thus presented to inspect a frame once embedded in masonry shows it to be remarkably well preserved, considered as a whole. On the other hand, our deductions should be made guardedly, because of what is after all a short lapse of time.



COLUMNS OF SEVENTY-FIRST REGIMENT ARMORY.

Just four years elapsed between the erection and the demolition of the structure. It was erected and painted in January, 1899. Mr. Just.

The use of particular kinds of paint, and the measure of protection which they afford, has been given undue prominence in the last few years. The question is not as important as the agent of the paint manufacturer would have us believe. He has occupied entirely too much of our time, and is to-day the *bête noire* of the structural engineer. For instance, the paint now used on the New York Elevated Railway structures, and which answers its purpose, is practically the same as that which has been used by the engineers of the road for the last ten years or more.*

It is true that the circular chimney stack, which was painted with another kind of paint, the red oxide of iron ordinarily used by local boiler shops, seemed badly rusted on the outside, in strong contrast to the well-preserved columns located close to the stack; but, as a matter of fact, this stack, on exposure, was found not to be corroded, but was well covered with pigment. It appears, however, that the heat in the stack had destroyed the oil. The pigment could be readily removed by the hand, and rapid corrosion set in soon after exposure. It would seem, therefore, that any conclusion as to the lack of protection afforded by the asbestos jacket is untenable. This emphasizes the important office of oil in paint, or rather, the less important part which the pigment takes.

The case under discussion also adds little or nothing to our knowledge as to how much protection was afforded by the paint used, beyond the contained oil, for it may be cited that the oil in the threads of the tie-rods and bolts was practically intact, and, where not broken by the nut, had formed a perfect protection against rust.

A further interesting development was the fact that the faces of the beam girders, stretching between the columns in the principal façade at some of the story levels, still retained an almost perfect coat of paint. Nor were they marked by any cement or mortar, but presented clean, black faces. It would appear, then, that at these points the front stone was not "backed" by brickwork, but was set away from the webs, and hence it may be concluded that, for limited periods, the steel, if only encased, is as fully protected as when embedded in brickwork.

While it may be granted that exposed iron and steel, when kept well painted, is protected against the deteriorating influence of rust, yet it is equally true that a sufficient number of instances have not been collated at this time to permit us to say the same of the painted steel frames embedded in the brick and stone walls of modern city structures, whose only excuse for existence is the use of walls of minimum thickness which they permit.

* *Transactions*, Am. Soc. C. E., Vol. XXXIII, p. 535.

Mr. Just. Instances, throwing additional light on this phase of the question, therefore, should be welcome. A better illustration than the "Pabst" Building, if measured by time, is found in the case of the Seventy-first Regiment Armory in New York City. Built for more than twelve years, and destroyed by fire one year ago, eight riveted (Z-bar) columns, Plate XXXII, which supported the main roof, now extend exposed from the northerly and southerly walls in which they were embedded. These walls, now removed for the upper half of the length of the columns, permit inspection. The columns, inaccessible for more than ten years, were probably subjected to considerable heat during the fire, and have now been exposed to the weather for more than a year. Notwithstanding all this, they show no appreciable deterioration by rust, which, while general over the surface, is only superficial. Paint, apparently the red oxide of iron used almost exclusively at that period, shows, in patches, where the brick filling has fallen away. It remains especially good between the flanges at the top for short distances below the cap, where the brick filling seems to have been omitted. For the rest of their length these columns were well enclosed on all sides by the brick laid in close contact with the metal. Much of this brick filling is still in place on the exposed part of the columns, and, where it no longer exists, the original courses of the brickwork are still marked against the columns by stripes of mortar.

An interesting case of column corrosion was recently noted in the uprights supporting the roof garden of the "New York Theatre," at Forty-fifth Street and Broadway, in New York City (Plate XXXIII).

The load of the all-glass roof is brought to the top of these uprights by four intersecting trusses having curved lower chords. For decorative purposes, a part of each column, commencing some distance below the intersection of the curved chords with the column, and extending down to the floor line, was enclosed by two thicknesses of scenery canvas, which had been painted on both sides, and which was stretched over galvanized-wire cloth, which in turn was carried on furring strips consisting of small pieces of unpainted wood. This arrangement kept the envelope entirely clear of the column. Proposed alterations caused the removal of these jackets, when it was found that every column was entirely incrusted with rust scale, from the base plate of the column, under the floor, up to the point to which the jacket had extended. The unpainted wood furring and the galvanized wire were in excellent condition. Beyond this point, the columns, as also the intersecting overhead trusses, had received a second coat of paint. This coat was of lead with a light green pigment, which would indicate clearly even traces of rust. All this upper work, however, was rustless, and the paint in good condition. The lower and much rusted part of the column, it was plain, had never received any other



FIG. 1.—COLUMNS IN ROOF-GARDEN OF "NEW YORK THEATRE."



FIG. 2.—CORRODED COLUMN IN ROOF-GARDEN OF "NEW YORK THEATRE."

paint than the "mill" coat, and, judging from what little remained, was of the usual red-oxide variety. Mr. Just.

It was evident that the canvas jacket, for its entire length, prevented the rapid evaporation of the water of condensation from the roof, the flow of which the curved chords readily directed to and down each column. These columns have been in place about seven years.

In contradistinction to this case, it is interesting to note the condition of the interior surface of structural members, built up of shapes, in a manner to form closed sections. Twenty years ago, when the type of bridge popularly known as the "Phœnix" was first meeting serious criticism, because of its cast chord and post connections, and inaccessibility to the interior of these members for painting, a wreck of the Bell's Gap Bridge on the Delaware, Lackawanna and Western Railroad permitted a careful inspection. It was then found that the original coat of paint on the interior of the posts and chords was generally in a very good condition, notwithstanding their exposure since the wreck. This bridge when wrecked had been in place about eleven years.

Disks cut from similar columns, supporting a blast furnace, showed the original coat of paint on the interior surface to be almost perfect. These columns had been in place about fourteen years.

As to the condition of iron when buried in certain kinds of earth for long periods, Mr. Colin C. Simpson, of the Consolidated Gas Company of New York, says:

"Of the two 'bar-shots' in my possession, the larger weighs about 20 lbs., and consists of a square wrought bar 10 ins. long, with cast-iron hemispherical heads. It was found in the Kingsbridge Road near Dyckman Street in 1893. The heads are almost in a condition as when cast, while the wrought connecting bar is only pitted superficially. The smaller 'bar-shot' is entirely hand-forged, and weighs 8 lbs. It was found in about the same locality in 1895. This shot is in a good condition throughout, and the hammer marks are still plainly to be discerned. Cannon balls of several sizes are so well preserved that some of them still retain the marks of the flask in which they were cast. The soil in which these shots were found is clean, dry and loamy."

He adds:

"These missiles were fired, at the time of the American Revolution, from the British frigate *Pearl*, anchored in the Hudson River, off or near Dyckman Street, during the attack on Fort Washington, in November, 1776. They have lost practically no weight since their use 120 years ago."

The effect of lime and cement mortars, or of concrete, on embedded iron or steel, while well recognized, has received considerable attention in this discussion. In this connection it may be stated that the framers of the "Building Code," which at present regulates the construction of buildings in New York City, recognized the protection

Mr Just. which such materials afford to iron and steel, when embedded in them.

Section 25 of this code reads:

"Where metal is incorporated in or forms a part of a foundation it shall be thoroughly protected from rust by paint, asphaltum, concrete, or by such materials and in such manner as may be approved by the Commissioner of Buildings."

What appears to be a more serious question than the corrosion of these metals, however, confronts those engineers who have been engaged in the construction of our tremendously large and expensive buildings. This is the recession of the water level, which is certainly taking place, at least, in the lower part of Manhattan Island. This recession, probably due in part, to the large increase in the number of "sky-scrapers," vaults and subways, must have exposed to decay many pile foundations where this method of founding was used.

In proof of this assertion it may be stated that, for a building recently proposed in that section of New York City, a pile foundation as originally designed had to be abandoned when, upon excavating the lot, it was found that the capping timbers and heads of the piles in the foundation of a large and prominent building adjoining on the

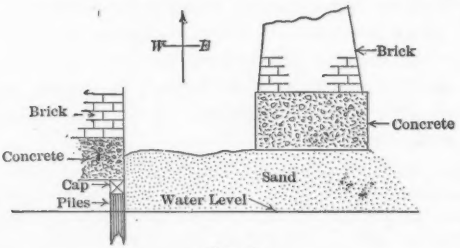


FIG. 1.

west were no longer protected by water (see Fig. 1). The indications showed that a recession in the water level of at least 2 ft. had taken place, in the last ten or twelve years, or at the rate of 2 ins. per annum. Lest it be assumed that the piles under this building were originally not cut off at, or below, the water-line, it should be stated, on the authority of the engineer connected with the design and erection of the building immediately adjoining the proposed building on the east, that the concrete footings of that building were laid in water. This concrete base, of course, was also shown to be high and dry when the lot between the easterly and westerly buildings had been excavated to a sufficient depth.

Mr. Gideon. A. GIDEON, Assoc. M. Am. Soc. C. E.—From the data submitted by those who have discussed the method of preserving steel, it would seem as though no hard and fast rule could be made as to whether or not structural steel embedded in concrete should be painted first; as it

depends largely on the conditions to which the metal is to be subjected, and the functions it is to perform. Each individual case should receive the careful attention of the engineer, and, not unlike many other engineering problems, is a question of judgment, guided by theory and experience. Mr. Gideon.

In cases where the adhesion of the concrete to the steel is of great importance, and where there is no danger of the concrete cracking and breaking off or peeling away from the metal, the previous painting of the steel would seem to be unnecessary, as the concrete would be an ample protection against rust, and greater adhesion of the concrete to the metal could be thus secured.

On the other hand, where the concrete is likely to crack and break off, thus admitting air and moisture, it would certainly be of the utmost importance to paint it as carefully as possible, and thus prevent it from rusting.

FRANKLIN RIFFLE, M. Am. Soc. C. E. (by letter).—The preservation of the steel frames of modern high buildings from corrosion is a matter of vital importance, not only to the engineer and architect, but to the general public as well. That the subject is not given the attention it deserves is only too apparent to the most casual observer. Mr. Riffle.

The writer knows of three skeleton buildings, now in process of construction, in which the columns and beams were neither oiled nor painted from the time they left the rolls at the mill until they were riveted in place.

At this stage they were given two coats of paint. Although the steel was badly rusted, no attempt was made to remove the rust before painting. The presumption is that the painting was designed to prevent further corrosion; but it is the writer's experience that paint applied to a coating of rust soon cracks and crumbles when exposed to the influences which promote oxidation. For this reason it is generally conceded, by engineers and architects who are familiar with steel construction, that paint, to be effective, should be applied to the clean metal, preferably at the shop, before corrosion begins, or, if later, not until every vestige of rust is first removed.

The fact that steel skeletons cannot be inspected after the buildings are completed and occupied should induce those who are directly responsible for their design and construction to take every reasonable precaution to preserve the metal from any possibility of corrosion. In the light of present knowledge, it is a grave question whether, under any circumstances, an architect is justified in assuming that the conditions in the interior of a building are such as to render corrosion impossible or even improbable. Examples are not wanting to prove that wrought-iron columns and beams encased in brick masonry sometimes corrode badly when not otherwise protected. In most steel-skeleton buildings the outside columns and beams are protected from the

Mr. Riffle. weather only by a mere shell of stone or brick. Walls of this character cannot prevent moisture from penetrating to the steel frame and causing oxidation. The engineer or architect who has faith in protection of this sort is paving the way for trouble. The failure of a single column or beam at some future period may result in serious consequences, involving the loss of both life and property. With such possibilities confronting him, is the engineer or architect justified in neglecting to adopt such precautionary measures, to render his work both safe and durable, as the present knowledge of the subject warrants?

Without undertaking to discuss the relative merits of the various steel preservatives now in use, the writer desires to call attention to the preservative qualities of Portland cement. Not many months ago, Mr. Geo. W. Dickie, Manager of the Union Iron Works of San Francisco, stated to the writer that for many years, and with very satisfactory results, he had used Portland cement to protect iron and steel from corrosion. He stated that while recently repairing the iron hull of a ship he had occasion to remove a portion of the cement floor which had been laid some forty years before. The iron beneath the cement lining was found to be absolutely free from rust. For years it has been Mr. Dickie's practice to line the iron and steel water tanks of ships with Portland cement, applied as a wash, by means of a brush. He is quite pronounced in his belief that a protective coating of this character is a far more effective preventive of oxidation than most of the paints used for the purpose.

The fact that Mr. Dickie's experience as a ship builder has brought him in contact with the most active type of corrosion (that caused by salt water) adds to the value of his observations, and is certainly a strong plea for the use of Portland cement as a steel preservative.

Mr. North. EDWARD P. NORTH, M. Am. Soc. C. E.—Speaking solely of wood pavements: The first wooden pavement of record in this country was laid in 1835, on Broadway, New York City; another piece, about 100 ft. long, was laid in William Street, New York City, during the next year. There is no record available of the time that this lasted, and possibly (if plank roads are excepted) there was no wooden pavement laid in this country from that time until about 1852 or 1853, when a wooden pavement, known as the Nicholson pavement, was laid on a bridge in Boston. For this pavement, a prepared bed of coarse sand was made, on which were laid 1-in. boards, swabbed with hot coal-tar on both sides, and on these boards blocks of pine, 3 ins. wide and 6 ins. high, were placed, after being dipped in hot coal-tar. A strip of wood, 1 in. x 2 ins., was placed between each row of blocks, and the interstices thus formed were filled with clean gravel and flushed full of hot coal-tar.

Afterward the same pavement was laid in Chicago, in 1857 or 1858.

From Chicago the use of this pavement spread over the West, and was brought to New York City in the time of Tweed. Mr. North.

Nearly all this pavement, with variants from it, rotted very fast. It was of untreated wood, and, further, was dipped in hot coal-tar, generally, but it was learned that with sufficient traffic such a wooden pavement would not rot before it wore out; that is to say, it would last six or eight years without showing any sign of dozing, if, during that time, it had sufficient traffic over it to wear it down from the original thickness to about $1\frac{3}{4}$ or 2 ins., when it commenced breaking up. But a pavement which was laid in places where the traffic was light very often commenced dozing in the course of two years, so that it was a shell at the end of five or six years.

These pavements, as laid in New York City, were so unsatisfactory, except one small piece in Fifth Avenue in the last of the seventies, that no wood pavement was laid until the end of 1895.

In England, the first pavement of record was laid in London in 1837. It was of beech. In London there was more or less continuous use of wood pavements, generally of hard wood, until about 1875, when patents were taken out by various persons, nearly all specifying that the wood should be treated with dead oil. In some the wood was saturated very thoroughly, and in others it was merely dipped in dead oil. A prejudice has grown up in England against treating pine or Baltic fir, which may be due to insufficient treatment, that of not saturating the wood fully.

Along in the last of the eighties, two specimens of wood grown on the southwest coast of Australia were brought to London for paving; one, the Karri wood, or *Eucalyptus diversicolor*, and the other the Jarrah wood, or *Eucalyptus marginata*. They are hard, reddish woods, with a rather peculiar odor, and it is said that iron driven into them will not rust. Pavements of these woods were laid in London with very great success, the claim being made that the Karri wood will last longer than the Jarrah. The Karri wood was brought over to this country and laid in New York City in the winter of 1895, on Twentieth Street, on the block between Fifth Avenue and Broadway, the pavement being accepted in January, 1896. It was laid on a concrete foundation. The bottoms of the blocks, which were 5 or 6 ins. high, were dipped about 2 ins. in a preparation of pitch, the composition of which was kept secret, the pitch being so hot and fluid that the coating was only about $\frac{1}{16}$ in. thick. The blocks were driven together as tightly as they could be, conveniently, and the top was covered with a very thin grout of fine sand and Portland cement. The west end of that pavement, toward Fifth Avenue, has been entirely wrecked by the construction of two large buildings with deep foundations. The eastern end, toward Broadway, has been left intact, and a large area of it has not been disturbed. That has now lasted a

Mr. North. few days more than seven years, as far as can be learned, entirely without repair, and it is in very good condition to-day, with the probability that at the end of four more years it will be in better condition than any granite pavement that has been laid in New York City. This is not a case of preserving wood, but of wood which preserves itself.

In regard to waterproofing brickwork, the attention of the members is called to a paper by the late William L. Dearborn, M. Am. Soc. C. E., read before this Society on May 4th, 1870, entitled "Experiments for Making Brick Masonry Impervious to Water, Tried on the Walls of the Back Bays of the Gate-Houses of the New Croton Reservoir in New York, and on the Brick Arch of High Bridge in 1863."*

*Transactions, Am. Soc. C. E., Vol. I, p. 203.

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PAPERS AND DISCUSSIONS.

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THE SANITARY DISPOSAL OF MUNICIPAL REFUSE.

An Informal Discussion.*

By Messrs. John McGaw Woodbury, Charles B. Ball, Charles H. Haswell and Rudolph Hering.

Presented at the Meetings of December 17th, 1902, and January 7th, 1903.

John McGaw Woodbury, Esq.†—In a large city, all sorts of wastes are found: Wastes of ashes, garbage, street sweepings and rubbish; the rubbish consisting of paper, broken-down sofas, discarded mattresses, old shoes, bureaus, washstands, broken crockery, dolls, toothbrushes, tin cans, rags, bottles. Every conceivable kind of waste is either found in the streets, or is put out of the houses, for the city to dispose of. What shall be done with it, has been and is still the question. Heretofore, in New York City, most of these wastes have been disposed of by the archaic method of dumping them into the sea. This is but an extension of the first idea of disposal, which was to throw such wastes into the street. Mr. Woodbury.

This idea of final disposition of refuse still exists in less civilized communities, particularly in tropical countries. It is practiced all through the West Indies, the only sewer being an open one running through the center of the street, into which it is the general custom to throw all wastes, including offal. They have but little ashes, and the carrion crow and turkey buzzard are the common scavengers.

* Continued from the *Proceedings* for February, 1903.

† Commissioner of Street Cleaning, New York City.

Mr. Woodbury. In New York City, at present, the speaker happens to be the common scavenger. In Paris, in the time of Louis XI, there was an order appointing the hangman as the common scavenger, and giving him permission to remove dead horses and cattle from the streets. The world has made much progress since that time.

The problem of garbage disposal is a vexing one. By the reduction process, phosphates and grease are obtained. By the incineration of garbage it is claimed that heat can be obtained, and that this will generate power; but all experiments in New York City show that it takes fuel to burn the garbage in a sanitary manner. The question of cost is important. The best or most scientific and sanitary process is not the best financially.

Fig. 1, Plate XXXIV, is a photograph of a flat scow being unloaded in the ocean, outside of Sandy Hook. It shows clearly the quantity of flotsam, much of which will be distributed along the beaches a little later.

Fig. 2, Plate XXXIV, shows the Barney Dumper being unloaded at sea. It is a divided boat, or catamaran, and splits in the center, thus dropping its load. It is a great improvement over the flat scow.

The Delahanty Dumper, going to sea under its own steam, is shown in Fig. 1, Plate XXXV. It is also a catamaran, having pockets hung between the two hulls. Doors, hung by hinges in the bottom of these pockets, are opened and closed by steam power, thus discharging the refuse. By the use of this vessel the refuse is disposed of at a cost of about 19 cents per cubic yard.

One of the dumping boards of New York City, with two Barney Dumpers and a flat scow, is shown in Fig. 2, Plate XXXV. This method of loading scows is also very archaic, as the ashes and light refuse are blown about by the wind. At these dumping boards, and on the scows while being loaded, a number of men are always engaged in picking over or sorting the refuse and trimming the scows. Quite a revenue is obtained by allowing the material of value to be picked from the waste, besides the advantage of having the scows properly loaded.

The output of rubbish and ashes from New York City is about 2 000 000 cu. yds. per annum. If the rubbish is separated from the ashes, it means a great deal financially. At Riker's Island land valued at about $10 000 an acre is now being made by using the ashes as filling, which is certainly more economical than throwing this material into the sea and letting it go to absolute waste. Ashes make the best possible filling, and pack well behind the cribs, which are sunk on the mud bottom.

It is of the utmost importance that dumping at sea be stopped, not simply because it makes the beaches unsanitary and unsightly,



FIG. 1.—UNLOADING REFUSE FROM FLAT SCOW, OFF SANDY HOOK.



FIG. 2.—THE BARNEY DUMPER, BEING UNLOADED AT SEA.

but because it is a waste of valuable material. The separation of refuse is now in good condition. The quantity of garbage sent to the Sanitary Utilization Company in 1902 was 30 000 tons more than was ever sent in any previous year. This quantity of garbage has come mainly out of the ashes. The rubbish, also, is now kept separate in parts of the city, thus leaving the ashes almost a merchantable commodity. Mr. Woodbury.

For the disposal of rubbish Mr. Parsons has designed the incinerator on the pier at Forty-seventh Street and North River. It is burning about 60 loads of 5 yds. each, or about 30 tons in eight hours, every day. This rubbish consists of excelsior, mattresses, trunks, barrels, boxes, chairs, sofas, paper, rags, etc. These, in burning, produce sufficient heat to make steam in boilers which will furnish power to run a belt-conveyer, now being constructed, which will be used for sorting the material. The surplus power will be used for lighting, for the elevator, for a traveling runway to the dumping board for loaded trucks, and possibly there will be some power which can be sold.

The City of New York now receives $110 000 a year for the privilege of sorting, and when greater facilities are given the sorters, as by the conveyer mentioned, a much larger sum will be realized.

Aside from the sanitary handling of the refuse, 63 acres of land have been made at Riker's Island, which is equivalent to $630 000; the privilege of picking over the refuse has been sold for $110 000 for the year; and the utilization of power from burning the non-marketable refuse will bring the total income up to about $900 000 a year. In this way the city's wastes become a source of revenue which will help materially in cleaning the streets.

Charles B. Ball, M. Am. Soc. C. E.—There are two inquiries which seem to be pertinent to this subject. One is the question as to how far it is safe and desirable to use street sweepings as material for filling. The second relates to precautions to be observed in handling builders' refuse resulting from the demolition of dwellings which have been for a long time in an infected condition. Mr. Ball.

The Use of Street Sweepings for Filling.

The division of municipal refuse into four classes, as used by Mr. Hering:

I.—Ashes;
II.—Street sweepings;
III.—Dry rubbish;
IV.—Kitchen garbage;

is a convenient one for the present purpose. It should be remembered that only in exceptional cases are street sweepings collected sepa-

Mr. Ball. rately, the usual method being to mix them, as found convenient, with any other class of refuse.

Premises.—To make clear the proposition advanced by the speaker, let it be assumed, at the outset, that kitchen garbage alone ought not to be used as material for filling low grounds, and that all mixtures of garbage with either ashes, street sweepings or dry rubbish are objectionable for this use to the degree in which they contain the more putrescible ingredients; also, that under some conditions ashes, and sometimes dry rubbish, may be utilized in this manner without danger.

The inquiry, then, is thus formulated: Whether street sweepings alone, or mixtures with ashes or dry rubbish, into which they enter as a principal element, are not undesirable materials for filling in low lands, parks and streets? It seems that this use of sweepings ought to be questioned, for three reasons: First, because of the considerable percentage of organic matter which they contain; second, because of the disease germs which are present in them; third, because of their objectionable physical qualities.

Prevalence of this Method of Disposition.—In connection with the general statements in Mr. Hering's opening discussion, that the use of sweepings for filling low land is a common one, certain data in *The Engineering Record* of November 29th, 1890, are of value. In a tabulated statement giving returns from seventy-eight cities and towns, as to the method of disposition of street dirt, which, doubtless, includes rubbish as well as sweepings, it is stated that fifty-four of these municipalities (69%) used such materials "for filling low places and private lands, or for grading streets and park grounds."

From the more comprehensive statement summarized by A. Prescott Folwell,* M. Am. Soc. C. E., from the detailed reports obtained for the "Municipal Year Book for 1902," it is learned that 741 of the cities and towns having a population in excess of 3 000 report that street sweepings are used for filling. This number is 76% of those that report upon the method of disposal. It may also be noted that the Department of Street Cleaning of the City of New York advertises that:

"Persons having lands or places in the vicinity of New York Bay to fill in, can procure, free of charge, material for that purpose—ashes, street sweepings, etc.—collected by the Department of Street Cleaning."

Quantity.—Although few statistics are obtainable as to the total quantity of street sweepings handled by municipal authorities, the ratio which the refuse thus classified bears to the total quantity collected is ascertainable for some of the larger cities, as well as the quantities of sweepings collected by them.

In a table prepared for the Advisory Commission to Mayor Hugh J. Grant, and published in its report in 1891, the percentage distribu-

* *Engineering News*, November 20th, 1902.

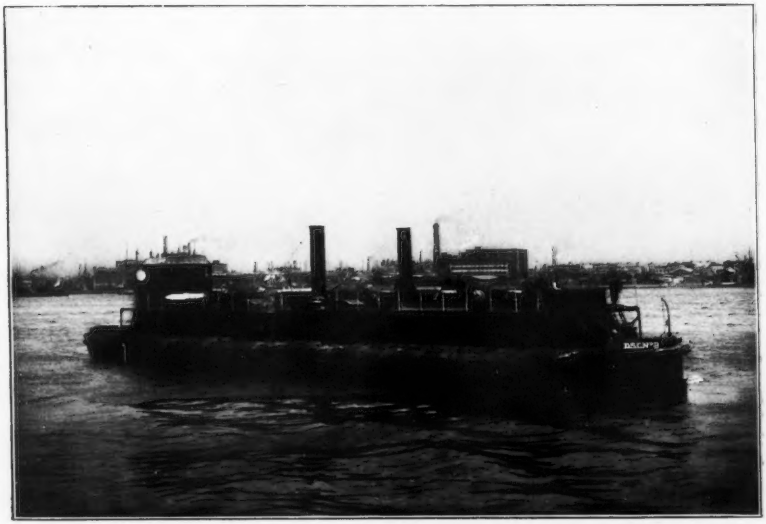


FIG. 1.—THE DELAHANTY DUMPER.



FIG. 2.—LOADING SCOWS WITH REFUSE.

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tion of the refuse collected in New York City in the years 1882–1890, is stated to be: Mr. Ball.

Ashes	about 62 per cent.
Garbage	12 "
Ice and snow	2 "
Street sweepings	24 "

The statement made by Mr. Parsons is that the distribution by volume is:

Ashes	57 per cent.
Rubbish	25 "
Garbage	18 "

There appears to be no difficulty in harmonizing these statements, it being understood that street sweepings and rubbish are included in a single item, and that the garbage constituent may often include many kinds of waste which, in a strict analysis, should be classified as rubbish rather than garbage. The latter table, by Mr. Parsons, showing the *per capita* distribution of the refuse in Greater New York, gives about 18% by weight of street sweepings. From these, and other less complete data, it would seem probable that 20% of the total amount of refuse well represents the proportion of such material in cities where the collection is made in well-defined classes, or that, at all events, such a percentage is not too large.

The report of the operations of the Department of Street Cleaning for the year 1900, which is the latest obtainable, states that it collected from all of Greater New York, 2 307 594 cartloads of "ashes, street sweepings and other refuse," apart from the item of garbage, separately named.

Composition of Sweepings.—The composition of street sweepings varies greatly with the character of the pavements from which they are gathered, with the method of sweeping—whether by hand or machine—and with the effectiveness of the separate collections of dry rubbish, such as dust, leaves, rags, paper, metal, old leather, straw, wood, glass, etc.

Organic Constituents.—It is obvious that sweepings from smooth, impervious, elastic pavements will contain much greater percentages of organic matter than such as are collected from macadam or rough stone pavements.

The limits indicated by Baumeister* are 4% for macadam pavements to 23% for stone pavements, and 60% for wooden pavements.

An analysis of street dirt made in 1874 by Professor Edwin Waller, for the Health Department of the City of New York, gave, for an average of thirteen samples:

Water	3.032 per cent.
Organic and volatile matters	28.454 "
Nitrogen	0.369 "
Mineral	68.514 "

* "Cleaning and Sewerage of Cities," 1891 edition, p. 177.

Mr. Ball. There appears to be no evidence to determine whether rubbish was or was not included in the samples for this analysis.

Examinations of the percentage of moisture, ash and organic and volatile constituents found in samples of ashes, sewer dirt, street sweepings and rubbish collected in New York City on two different dates, March 14th and May 1st, 1902, give percentages of the organic constituents varying from 17.86 to 40.70. The average of five analyses for each of the above dates was 26.31% of organic and volatile matters. The samples were collected by the skilled chemist who made the analysis, and garbage was excluded.

The prevalence, at the present date, of sheet-asphalt for street surfaces, as well as the constant increase in the ratio of paved to unpaved streets, would be likely to indicate that a higher percentage of organic matter is common, and it would seem that an estimated percentage of organic matter in sweepings at least as high as 35% would be justified.

Rubbish Constituents.—If street-cleaning machines are used instead of hand-sweeping methods, the resulting refuse will contain a smaller quantity of miscellaneous rubbish, as the sweepers and shovelers in the latter case collect from the gutters various articles of small dry rubbish which the machines do not touch. Most of these materials, such as leaves, paper, straw and hay, are light and combustible, but considerable quantities of waste metals, glass, crockery, plaster, etc., are heavy and incombustible.

Germ Constituents.—In addition to the tuberculosis germs noted by Mr. Hering as being abundant in street dirt, the bacilli of diphtheria are by no means uncommon, and typhoid fever germs are sometimes found.

A series of experiments was conducted by the Street-Cleaning Department of the City of New York in August, 1902, by exposing Agar plates, at the curb level and 6 ft. above, in various locations distributed over the city, and noting the number of colonies of bacilli developed during a stated period. The isolation of specific pathogenic germs was not attempted, to any considerable extent, the object being to determine the varied effect of different kinds of traffic in distributing the bacteria in air; but a maximum of 30 colonies per inch-minute was found in the east-side tenement district, and a minimum of 0.06 colony for a suburban street in the Bronx.

The important question respecting the danger from these bacilli is that of their viability.

It is now well known that the tubercule bacillus retains its life properties for long periods when dry, but it is not so well demonstrated that it is dangerous when in a moist condition, such as would occur most frequently beneath the surface of a fill. Respecting the life of the typhoid and diphtheria bacilli, there appears to be no doubt that these are perpetuated in damp surroundings.

Professor Charles Harrington, in his "Manual of Practical Hygiene" (1901), discussing the function of the air as a carrier of infection (pages 226–230), summarizes the extensive researches of Dr. Eduardo Germano on the permanence of typhoid with the statement that "this germ as well as that of diphtheria can live for a long time in moist surroundings." Mr. Ball.

G. Lister Sutcliffe, in an introductory chapter in his "Sanitary Fittings and Plumbing" (1901), says:

"Dr. Sidney Martin's experiments with the typhoid bacillus, for example, prove that it soon dies in 'virgin' soils, whether these are sandy or peaty, but that it rapidly multiplies in moist sterilized samples of soils from gardens and other cultivated places, and retains its viability and vegetative properties for months and perhaps years. Moist sterilized soil which had been impregnated with the typhoid bacillus was found to contain the bacillus at the end of 450 days. The soil was then naturally dried for 49 days, till it 'could be readily powdered into a fine dust;' the bacillus was still there.

* * * * * * * *

"The lessons to be learnt from these and other investigations are that some pathogenic organisms are not by any means so short lived as is commonly supposed, that they may spread rapidly under suitable conditions, and that they may exist for a considerable time even in dust so dry as to be blown about by the wind."

Physical Characteristics.—It is evident that the physical qualities of permanence and stability, required in ground to be used for foundations of structures, or even for the sub-surface of streets and parks, are lacking in street sweepings, owing to the considerable quantity of organic matter and light combustible material contained.

Conclusions.—That the opinions expressed by the speaker are not altogether new, is shown by a paper on "City Scavengering at Boston," read by Eliot C. Clarke, M. Am. Soc. C. E., at the meeting of the Metropolitan Public Health Association in Nashville, Tenn., on November 18th, 1879. The work of scavengering is here classified as constituting four parts:

1.—Removal of offal;

2.—Removal of ashes and house dirt;

3.—Cleaning of streets and street basins;

4.—Cleaning of privy vaults and cesspools.

Under the second division of his subject, Mr. Clarke writes:

"A large part of Boston being very low land, there is great temptation to use this refuse (ashes and house dirt), in the place of earth filling, and such is its usual disposition. If the ashes were perfectly free from admixture with other substances, it would form suitable filling for most purposes, but it is not so."

He then explains the attempts to keep out objectionable rubbish, and, in the following statement, summarizes the failure to accomplish this:

"On an average, nearly one-third of each cart-load of so-called ashes consists of other refuse. Portions of this refuse are harmless

Mr. Ball. enough, as, for instance, broken glass, crockery, plaster, old iron and tinware, but other portions entirely destroy the suitability for filling, such as bones, hair, leather, rubber, paper, pieces of cloth and carpeting, old baskets, and, in short, any vegetable or animal matters liable to decompose. The ashes and house dirt are used to grade streets and parks belonging to the city, and private lands, when desired or permitted by the owner. In a few cases a small sum is paid to the city for the filling. It is evident that the presence of the refuse house dirt renders ashes undesirable for street building, as the matter, as a whole, compacts very slowly, and continues to settle for years. If the surface be paved or covered with gravel, there will probably be no smell; but digging trenches for laying gas and water pipes, sewers and drains, will be an offensive operation for a number of years, since organic matters, kept from a free supply of oxygen, decompose slowly.

* * * * * * * *

"It is probably a serious mistake to dump house dirt on land which is to be built upon. It is true that the organic matter mixed with the ashes must in time disappear; but how soon, it is impossible to say. Excavations made in Boston in land filled from city carts ten years previous have disclosed remnants of organic matter, and the process of decomposition is still going on. The risk in living over such land may be slight, but, however slight, it is a risk of disease and death."

In considering the third division of the subject, he writes:

"Forty-eight thousand and fifty-nine (48 059) cart-loads of dirt (street sweepings) of 40 cu. ft. each, were collected during the past year (1878?), and were disposed of in the same manner as ashes and house dirt, by being used to fill land for streets, parks and dwelling lots. The street dirt is of a rather uniform character, consisting of earth, road detritus, fragments of wood, leaves, paper, soot, hair, etc. Under exceptional conditions, from well-paved streets in the heart of the city, a load is sometimes obtained of sufficient manurial value to fetch a small price for use on land, but this is seldom. It is a manifestly unfit substance for filling, both from an engineering and from a sanitary point of view; but what else to do with it is a problem yet unsolved."

To the speaker, the solution appears to be a clear one, in view of the statement by Mr. Parsons, that "rubbish collections are very combustible, as are also street sweepings." The conclusion appears to be incontestable that street sweepings may and should be burned, irrespective of the question whether they can or can not be made to assist in disposing of the more objectionable garbage.

The Demolition of Infected Dwellings.

It has been recognized for some years by students of sanitary science that human habitations in which filthy conditions prevail for a long time become so infected with disease germs that no cure can be effected. Although the recent methods of disinfection by formaldehyde gas are to a degree effective, it seems questionable whether even those will render safe for habitation a dwelling which has for a long time been permeated with disease and filth.

Danger of Infection.—The report of the Tenement House Commit- Mr. Ball.
tee of 1894 (usually called the Gilder Commission, from R. W. Gilder, its Chairman), makes a brief reference to their conclusions in this regard, as follows:

"It is a well-known fact that human dwellings, by prolonged occupation, become so saturated with the bodily emanations of those who have lived in them, sick and well, as to be less healthy than newer houses. It has often been proposed to construct hospitals of flimsy and inexpensive material, after the manner of a temporary shelter, and destroy them by fire every few years, to be replaced with new ones.

"This result of prolonged human occupancy is made worse in this city by the rapidity with which the character of the population in the lower parts of the city has changed, and the fact that houses built as private dwellings are not fitted to serve as tenements, either in respect to light, ventilation, water supply, privacy or facilities for cleanliness."

Respecting the fact of tuberculosis infection in old houses, there is no higher authority than Arthur R. Guerard, M. D., of New York City. In a paper presented to the Tenement House Commission, November 16th, 1900, treating of "The Relation of Tuberculosis to the Tenement House Problem," he says:

"It has been repeatedly observed that some houses in overcrowded districts after a time seem to become permanently infected with tuberculosis, as evidenced by a repetition of cases of the disease. * * * It is easy to understand how the permanent infection of premises may occur when one considers that the sputum of consumptives, which frequently contains a countless number of virulent tubercle bacilli, is often carelessly expectorated on the floor and elsewhere in dwellings, where it dries and is converted into dust, thus getting into cracks in the woodwork, in the papering, etc., whence it is later inhaled into the lungs by others. Such tuberculous dust has been found by experiment to remain virulent and infectious for months and even years after it was deposited in rooms which were not thoroughly disinfected and renovated; and where this dust is allowed to accumulate for a length of time it may be impossible to disinfect and renovate the premises without practically rebuilding them. These premises then become permanently infected."

John F. J. Sykes, M. D., in his recent book on Public Health and Housing, thus refers (pages 82 and 83) to the dangers of infection:

"Miquel, Emmerich, Carnelly, Haldane, Anderson, Johnstone and other observers and experimenters have shown that with the increasing use and age of a dwelling-house the walls and spaces beneath floors become liable to harbour micro-organisms to an increasing degree. The more the surfaces, especially the floors and walls of a house, become worn and defective, the better lodgment they present for the accumulation of organic matter—the nidus of micro-organisms—and the less attention paid to repair and redecoration, the more unhealthy the influence of the house becomes.

"All these experiments and observations indicate the necessity for such construction, maintenance, and usage as best conduce to the

Mr. Ball. cleanliness and purity of the air in and around dwelling-houses, in order not only to prevent disease, but also to prevent the loss of that vitality, vigour, and energy which cannot easily be measured by experiments or by statistics."

The conclusions of these various investigators as to the danger in the use of such dwellings, appear to the speaker to justify reasonable precautions in their demolition, and in the handling of the materials, both the valuable and the useless, resulting from this tearing down.

The number of buildings for which demolition permits were issued in 1902 by the Bureau of Buildings, Borough of Manhattan, Greater New York, was 1 622. This number, it is well understood, does not represent all the buildings demolished, as a small proportion is torn down without the formality of a permit. If this list is examined by anyone conversant with the city, he will note, from the street locations, that certain of these demolished dwellings are very old buildings in tenement districts, and in some cases such as were not constructed originally for tenement purposes. A search of the records of these buildings will show that they are infected with disease, and have been for a long period in unclean condition.

Present Method of Demolition.—The present method of demolition results in the removal, for fuel purposes, by the poor of the neighborhood, of the smaller portions of the wooden floors, casings, roof, etc., which are then stored in the adjoining cellars. It results from this that a building infected with disease germs, filth and vermin, may readily disperse these dangerous elements in the vicinity.

The only supervision of a sanitary nature over the practice of demolition in New York City at the present time is the requirement by the Department of Health that frequent sprinkling with water should be given to the walls as they are torn down, in order to avoid objectionable dust.

Desirable Precautions.—It would seem to the speaker desirable to examine all buildings, about to be demolished, as to their sanitary condition, and, if this is found to be at all doubtful, to observe the following precautions in their destruction: First, that the building should be kept constantly wet with a disinfecting solution as the work of tearing down proceeds. From what has been stated already, it is evident that the old paper on walls and ceilings, the plaster of walls, and the woodwork of the floors, doors and trim of the rooms and halls are the elements of danger. These should be sprayed thoroughly at the commencement of the work, and kept wet. The Building Code of the City of New York requires the demolition of buildings to be carried on story by story, and the systematic execution of the work as indicated herein would be facilitated by the adoption of this rule in all cases.

Second, that no combustible material should be distributed in the neighborhood, but that it should all be removed, and that which is valuable for fuel only thus used under conditions which would pre-

vent the danger of contagion. The old paper, lath, floors, doors and trim of the rooms should be burned at some locality remote from any residence, and, by the use of simple gratings, will furnish fuel for the incineration of much of the light refuse. Mr. Ball.

Third, that any portions of the structure which are suitable for use in new buildings should not be thus used without having been subjected to suitable disinfecting processes.

Fourth, that, during the process of further excavation of the site, the soil removed should be examined as to polluting matters, and, if found to contain such, it should be treated with disinfectants. The actual demolition of old tenements in New York City, with the excavations for cellars of new buildings, shows that, where school sinks and earthenware house drains have existed, there is an extended saturation of the soil. The removal and proper treatment of this saturated soil is a matter of great importance.

Fifth, that all non-combustible waste refuse should be kept under supervision, as to the method of disposal. Where it is impracticable to treat any waste material by some process of sterilization, the disposal should be at some locality not likely to be used, even in the remote future, for residence or business purposes.

CHAS. H. HASWELL, M. Am. Soc. C. E. (by letter).—The introduction of water into towns and cities for domestic and public services, other than that obtained from public and private wells, involves the laying of pipes for its reception and transmission, and of sewers for its discharge in combination with the excrementitious matter of their residents and animals, the filth of hospitals, households, slaughter-houses, stables, manufactories, tanneries, street washings, etc. The resultant of this flow is the pollution of the earth or water over or into which it is discharged. Mr. Haswell.

The disposal of crude sewage and its treatment, the mitigating of its septic elements, its sanitary, useful and effective disposal, combined with the resulting pollution of the rivers into which it is discharged, and the insanitary effects thereof, is becoming a subject so important, as relates to the existence and duration of human and animal life, that it imperatively demands immediate consideration and action. It is of more national importance than the aggregation of all the financial and political questions of the time; yet, with the exception of the consideration and report of the St. Louis Commission on the Chicago Drainage Canal, and possibly some other isolated cases, it is criminally neglected.

Primary Disposal.—In internal villages or small towns it is customary and quite practical to mix the excreta with earth, bear it beyond the residences of inhabitants, and use it for fertilization, or deposit it in masses and cover it with earth. In the more populous towns of Europe, trenches are excavated and filled, the ground selected being

Mr. Haswell. suitable for infiltration of the fluids of the sewage reservoirs and cesspools, and being located at a proper distance from residences. When filled, these trenches are covered with earth, the surface of their contents, meanwhile, being exposed to evaporation, and their whole contents to infiltration (their masonry being open-jointed); but when the earth in which they are placed is clay, wet or saturated, or is contiguous to a stream of potable water, they are constructed with close joints, and, periodically, their contents are pumped out and distributed for fertilization.

Treatment.—In order to mitigate the noxious exhalations of crude sewage, it is, in some instances, delivered into tanks, reservoirs or coke-beds, for aeration, subsidence, filtration and oxidation.

Chemical Purification and Precipitation.—Chemical purification is effected by a strong mixture of lime, salts, sulphur, oxidizing compounds, etc., with the crude sewage. Iron and aluminum salts, if followed by lime, give a purified effluent.* Precipitation is effected by the use of lime in solution, and by sulphate of alumina. In populous towns and cities, any like treatment of their sewage, in consequence of its volume, is wholly impracticable.

Surface Precipitation.—This involves the occupation of a large area of land, it being officially estimated at one acre for every hundred of human inhabitants.

In the course of purification, oxidation is an essential portion of the changes through which sewage has to pass. Sedimentation or subsidence of the solid and dense material of sewage is claimed to arrest pollution; if so, the effect is retroactive, as it would result in the gradual filling up of the bed of the river, by the formation of foul and noxious shoals. The natural purification of water, to the very slight extent to which it is attainable, is effected by the combination of ammonia, arising from the mixture of decomposed animal matter, with the oxygen of the atmosphere.

Filtration.—In order to arrest bacteria and organic matter by this process, sewage is delivered into reservoirs and subjected to the absorbent capacity of coke and sand; which operation involves the frequent cleaning or replacing of these materials, as their absorbent capacity will soon become inoperative on account of the arrest of the dense particles of the sewage.

Infiltration.—Infiltration is classed by Rideal under three divisions as Broad, Intermittent, and Mixed.

Broad.—In broad infiltration, the sewage is distributed over large surfaces of agricultural land, or sewage farms, as they are termed, on which it is purified. This method involves the occupation of very large areas of land, officially estimated, like that of precipitation, at one acre per hundred of population.

*Samuel Rideal, D. Sc., London. John Wiley & Sons, N. Y.

Mr. Haswell.

Intermittent.—This is effected by the deposit of sewage at short intervals of time, on an area of porous earth as restricted as will absorb it, but making the products of vegetation of secondary importance.

Mixed.—In the mixed system, the sewage is first purified by sedimentation or by chemical means. The efficiency of this operation depends wholly upon the character of the soil, as to its porosity and freedom from water, saturation, clay, peat, or conglomerated gravel. The Local Government Board of England prescribes for stiff clay one acre for every twenty-five human inhabitants, and for loamy gravel one acre for every one hundred.

Cremation.—Cremation is effected by the evaporation and the combustion of the crude sewage at a very high temperature, a forced draught in the furnace, and a very high chimney to dispel the noxious effluvia of the combustion. In the operation of some furnaces in England, it was essayed to prove that sludge (precipitated and dense sewage), both remuneratively and without offence, could be incinerated, and that the coke produced paid for the operation. It was found, however, that the agricultural value of the residuum was so much impaired that it could not be disposed of profitably for that purpose. The evaporation of the liquid, and the combustion of the sludge requires the consumption of some fuel. When the sludge is submitted to a filtering pressure, an average of 7.74 tons (2 240 lbs.) per million United States gallons of crude sewage is obtained. At Southampton, England, it was essayed to burn sludge remuneratively, and without noxious results. The combustion of coal was first used to try it, the ammonia evolved was collected and the volatile matter was passed through the fire. It was claimed that the value of the coke produced paid for the cost and expenses, and that the net cost of the combustion and incineration was inconsiderable. In support of this operation, it is to be considered that even where sewage is discharged into bays upon the sea coast and below the confluence of the tidal and river flows, the velocity of the ebb tide is not wholly effective in transporting it to the ocean, as it will subside in slack water, and in the basins (locally and erroneously termed slips) formed by the projection of piers, thus creating noxious exhalations, and causing frequent dredging and the transportation of their contents to the ocean.

Fluid Discharge and River Pollution.—Where towns and cities are located on a long river, and above the extreme line of confluence and commixture of its water with the tidal water of the ocean, as some on the Hudson, Delaware and Connecticut in the East, and on the Ohio, Illinois, Mississippi and Missouri in the West, the pollution of the water by the discharge of crude sewage into it is increased progressively by the discharge from other and adjoining towns, but somewhat mitigated by the gradual addition of water from tributary streams (which,

Mr. Haswell. however, will eventually become polluted in like manner), down to the point of its confluence with the water of the ocean.

Effect of Pollution.—It is generally, if not universally, claimed that foul or polluted water purifies itself, and, in support of this claim, tests and observations have been made. Thus, the Massachusetts Board of Health deduced that if the crude sewage was less than 0.0077 ($\frac{1}{130}$) of the water of a river into which it was discharged it would not affect the water objectionably. In other words, it is advanced that if one measure of crude sewage is mixed with 129 measures of river water in its normal condition it would yet be potable, notwithstanding that its septic or putrefying quality would not be negatived or eliminated. Further, an investigator in Europe has declared that if the crude sewage does not exceed 0 066 ($\frac{1}{16}$) or 6.7% of the river water, when it flows with velocity equal to that of the sewage, it would not affect the potable quality of the water; notwithstanding that, in addition thereto, all streams and rivers are polluted more or less by the rain washings from farmyards, roads, decayed vegetable matter and the putrefaction of dead animals.

As to the distance in which crude sewage discharged into a flowing river will become innocuous by the alleged self-purification of the water, authorities differ, as one puts it at 25 miles and another at 200. The desirability of assigning any general distance, assuming it practicable to do so, is negatived by the point of location at which any putrescent matter was present. Thus, a putrefying carcass of an animal, by its gravity (for instance, that of a dog with a weight attached to it), may remain at the bottom of a river. Over this the water would flow, and receive putrescent matter from it for a long time.

While it is conceded that pure water is only chemically obtained, in a laboratory, natural water is acceptable for domestic requirements, provided it is free from noxious matter, and is not offensive to taste or injurious to health and commercial requirements.

Notwithstanding the popular declaration that even crude sewage, discharged in flowing water, will, when mixed with it, in various assumed and empirical proportions and assigned distances of flow, become potable, a knowledge of the various impurities of such polluted water is not pleasing to reflection. The riparian inhabitants of the river into which the sewage of a populous city flows are passively subjected to the drinking of its water of pollution, yet, at the same time, they will consider the presence of any, even slight, impurity in their other fluids or foods, as milk, mineral waters, flour, meats, fruits, etc., as objectionable and not to be submitted to passively. As to the "self-purification" of water, it is difficult to manifest how the many and various chemical, vegetable and animal pollutions can be eliminated from polluted water by any process, physical or chemical, and unless they are eliminated, the assertion that water will purify itself

is a common and grievous error, and, despite the claims of chemists and scientists of all grades, they are challenged to manifest in what manner, chemical or self-acting, water infused with excrementitious matter, the discharge of tanneries and slaughter-houses, paint, ink and glue factories, hospitals of all kinds, dead bodies of men, animals and fish, can be made acceptably palatable. A whole is an aggregation of its parts, and if a volume of foreign or offensive matter, however small, is introduced into pure water, its purity is negatived. Mr. Haswell.

Insanitary Effects.—Living animals cannot retain health while the discharged products of their vital action are permitted to be retained about them, and when they are confined in that condition death gradually ensues. The result of a sanitary disposal of fluids is illustrated in the improvement of the health of towns by the reduction of their death rate. An instance is the City of Leeds, England, where, in twenty years, the death rate was reduced from 28 to 18 per thousand of its inhabitants.

In towns and cities where infiltration is wholly depended upon for the disposal of sewage, the soil becomes contaminated with fæcal matter, which, undergoing but little oxidation and in combination with the periodical cleaning out of the cess-pools or reservoirs, renders the exhalations therefrom both noxiously offensive and insanitary. In the country and in some small towns it is customary to avail of streams over which to set privies, and when the streams are sluggish the fæcal matter will subside in its flow and pollute the earth to an extent affecting its sanitary condition.

Reviewing, then, the elements submitted, it is presented:

1st.—That for internal villages and small towns, sewage can be readily disposed of by infiltration in and the fertilization of the adjoining soil.

2d.—That for similarly situated and larger towns and small cities, while the sewage can be infiltrated to a serviceable extent and the solid portion used for fertilization, yet the area of soil required for effectual operation is so great as to render this method generally, if not wholly, impracticable.

3d.—That from all locations, from villages to populous cities, on tidal rivers or sea coasts, up to the clearly defined limits of the tidal flow or confluence with the fresh-water flow, their sewage may be discharged directly in its crude condition, as instanced in the sea-bound cities of Boston, New York, etc., Burlington on the Delaware, etc.

4th.—That if the discharge of sewage, crude or treated, into our rivers is continued, it will wholly arrest them from being resorted to for the supply of potable water, and supplies must be obtained from the ponds and lakes with which our country abounds. Animal life cannot exist in polluted water, and the cost of arresting its pollution,

Mr. Haswell. in view of its result, is not to be considered. As the health of our people is of primary importance, the emergency must be faced.

5th.—That to draw upon the waters of Lake Michigan and its northern tributaries for the service of the Chicago Drainage Canal and the mitigation of its pollution of the rivers into which it is discharged, and by assigning a given volume of it, *pro rata* with the number of population of the City of Chicago, would result in the lowering of the surface levels, and all adjoining waters down to the Gulf of St. Lawrence, and be prejudicial to both the manufacturing and commercial districts of all the intervening towns, as a consequence of which it would not be permitted, either by the Government of the United States or that of Canada. Hence the proposal is utterly impracticable of adoption, as its effects would soon become so insupportable to the people of both countries that they would arise in opposition, and Congress would be appealed to for relief, and damages be claimed.

6th.—As the sewage of populous towns and cities cannot be disposed of effectually, or with sanitary requirements, either by evaporation, precipitation, filtration, or its discharge into rivers above the line of commixture of tidal and fresh waters, or into lakes, or by mixture with great proportional volumes of water from our lakes, with immunity from the pollution of the potable waters thereof, there are but two methods left, viz., one for populous inland towns and cities, the sewage of which must be chemically discharged of its noxious exhalations and disposed of for fertilization, if practicable to do so; and the other by cremation, in which there is no danger of the pollution of water supplies, or insanitary effects. To operate it, involves the construction and maintenance of a furnace plant, and that the sewage, as received, must be as free from surface fluids as practicable, and that where sewers for the reception and conveyance of both sewage and surface water exist, as in large cities, independent drains be laid for the surface water.

7th.—That, great as this combined cost of reconstruction and construction would be, it is so inconsiderable, compared with the beneficial results to be attained by it, that the expenditure is not to be entertained as a bar to the method, for the result of the discharge of the water of our rivers above the line of commixture given will soon have to be faced squarely, as the destruction of the potability of the water of all rivers bordered by populous towns or cities will become eventually so extensive that it will interfere with the requirements of the people and of their horses and cattle. It will also cause the destruction of the fish, and how it is that the citizens of Chicago entertain the opinion that the operation of their drainage canal will be submitted to, and that the riparian residents of the rivers into which its sewage is discharged will submit to it passively, is wholly inexplicable to the writer.

8th.—That the discharge of sewage, crude or treated in any antiseptic manner, in a fresh-water river, is offensive, noxious and not to be entertained with any regard whatever to the sanitary requirements of its riparian residents; that it will not be submitted to; and any or all towns or cities contributing to the pollution of such water will not only not be permitted to continue in such practice, but will inexorably be required to dispose of their sewage in some other and proper manner. Mr. Haswell.

9th.—That existing wells, for households, in densely populated towns and cities should be filled up and abandoned forthwith, and the vaults of all privies and tanning vats made water-tight, to arrest infiltration of any part of their contents to contiguous and subterranean watercourses, and to guard against the result of the ignorance and indifference of some people who disregard all sanitary requirements and permit the proximity of privies to their wells.

Finally, when this subject of the disposal of sewage is entertained in a proper manner, and such disposal is operated under sanitary requirements, the wonder will be how and why it was that any of the now existing methods, including the very restricted operation of cremation, for populous inland towns and cities, were tolerated.

WRITER UNKNOWN*.—The sole reason why cremation of garbage has been a success in England is that it is burned in ovens and not near boilers; that is to say, the cells in which it is destroyed are wholly of firebrick, and only when combustion is complete are the products brought into contact with the comparatively cold plates of a steam boiler. There is really no very serious difficulty in completely destroying refuse at a high temperature, as a simple calculation will show. Anyone who has a garden knows that ordinary garden rubbish, leaves, etc., will destroy itself if heaped up high above a small quantity of dry stuff. The initially dry stuff dries out the wet stuff which lies upon it, and this then burns and the whole heap is dried off and burned. Writer unknown.

In England all refuse is collected together, *i. e.*, not separately, and includes ordinary house refuse, such as cinders and vegetable refuse. It is considered that this material contains 30% of water, 30% of combustible matter and 40% of inert matter, such as gravel, broken crockery and clinkers or ashes.

As carbon contains 14 647 B. T. U. per pound, 1 lb. of average refuse will contain 4 400 B. T. U. At 1 500° Fahr., the water will carry off less than 550 B. T. U., including latent heat and superheat. There will remain 3 950 B. T. U., to deal with. Allowing 18 lbs. of air per pound of fuel, there will be 54 lbs. of air, 0.3 lb. of fuel and 0.4 lb. of mineral matter to be heated up to a temperature of, say, 1 500°, or a

* The manuscript of this discussion was received by the Secretary, from London, but no name was attached to it in any way. It is published here in the hope that the writer will furnish his name, so that it may be printed in *Transactions*.

Writer unknown.

total of 6.1 lbs. to share in 3 850 B. T. U., or 631 units per pound. The mean specific heat of all furnace products and clinker, etc., is less than 0.25. Calling it 0.25, the resultant temperature would be 2 524° Fahr., or 631 × 4, which is sufficiently above 1 500° to allow for further excess of air. Moreover, as the air forms by far the larger weight of stuff passing through the furnace, it becomes a simple matter to add considerably to the temperature by heating the air in the flues beyond the destructor.

The reduction of temperature, due to the increase of specific heat of gases at high temperatures, need not be discussed. It will not pull down the temperature below 1 500 degrees.

The combustible elements in any refuse can be ascertained easily by having a bulk sample weighed and burned off in a gas retort, after being first dried, and again weighed, the second difference being combustible. If a refuse is so poor that it has not sufficient fuel in it to burn thoroughly, it ought to be mixed with the cheapest grade of coal obtainable and all burned together in a refractory cell. The placing of a boiler as one boundary of a destructor cell is the worst possible practice. Even good bituminous coal cannot be destroyed by such a device without smell and fumes.

The sloping grate, of course, is a great aid to the work, for the labor then consists only in helping forward the clinkered purified residue. The heat carried off by the water is partly recovered when the gases are passed finally through a boiler; but no sanitary engineer now attempts to use the heat from a destructor until destruction is complete and nothing but glowing gas remains. A simple calculation for any ordinary sample of refuse will show that it has power to heat up everything it contains to a clear red heat or higher.

Mr. Hering.

RUDOLPH HERING, M. Am. Soc. C. E. (by letter.)—The discussion has revealed a fair unanimity of opinion regarding the fact that the garbage question has now reached a point when its proper solution requires the aid of the engineering profession, instead of being left for solution almost wholly to committees of city councils or of boards of health. It is also apparently agreed that different conditions demand different methods of disposal, and that each municipality should select the method which, after a careful study of the specific local conditions and a careful investigation of the cost of securing unobjectionable results, proves to be most economical.

It is further agreed that the problem must include a consideration of the methods and cost of handling all of the several kinds of refuse between the points of origin on the streets and the points of final disposal.

When opening the subject, its largeness precluded entering into details, but a number of these have been elaborated subsequently, and have added valuable information.

Mr. Hering.

In reply to Mr. Baldwin the writer may state that there are at least three garbage furnaces in America, where, it is said, all the refuse is burned without the regular addition of coal, excepting to start the fires on Monday mornings, or whenever they have been interrupted. One is in Montreal, where the garbage is mixed with dry refuse and with domestic ashes, which, however, are screened at some seasons if not always. Another is at San Francisco, where there is a similar furnace and where the garbage is likewise mixed with dry rubbish and ashes. The third is at Atlanta, Ga., where the garbage and dry rubbish alone are burned, and no domestic ashes with the residuum of unburned coal, are added.

The writer was glad to hear from Mr. Parsons that his investigation had convinced him that the garbage and refuse in New York City, when mixed, would be self-combustible. Steam ashes, being the result of intelligent and economical firing, have no fuel value left, and always should be removed separately and utilized for filling, road-making, or as the body-material of mortar. But domestic ashes, containing 20% of unburned coal, have a fuel value beyond the cost of screening out the fine ashes, which value may be sufficiently great to utilize. Whether or not such utilization is economical, depends on the extra length of haul to the crematory, and on the cost of screening.

It would be very interesting and useful if the precise facts leading up to Mr. Parsons' conclusion could be made public. Generally, he intimates, the scientific treatment of garbage is fairly understood and could be put into practice, provided the means were available. But this understanding is not the only requisite for a solution of the present difficulties. It is also necessary that the public should appreciate it fully and have confidence in the recommendations, because the public must furnish the means to carry them out. To this end, an actual demonstration on a practical scale seems to be the *sine qua non*, showing that the treatment which engineers, after studying the special problem, believe to be the proper one, will be both successful and economical. Such a demonstration is yet lacking in our own country.

Most of the present disposal works were proposed by promoters, who succeeded in obtaining contracts to erect plants, and whose interest lies chiefly in immediate profit to themselves. An impartial and thorough investigation, in order to ascertain the best methods and results for ultimate instead of for immediate profit has not yet been undertaken by any city in this country. Dr. Soper states that the present moment is propitious for such an investigation to be made as regards New York conditions, where the existing methods are yet crude and quite expensive, even though 40% of the work of collecting and disposing of the garbage is done by private parties, over which the city has but little control.

The writer suggests that in his opinion a further profitable inves-

Mr. Hering. tigation would be a full and detailed report on the entire subject, containing itemized expenses, and setting forth clearly the methods of operation and the results obtained in those cities of Europe where this subject has been settled satisfactorily, and, for comparison, an equally detailed report on the existing conditions in several of our own cities. Such a comparative report, the writer believes, would be of great value in pointing out specifically and most forcibly the courses to be pursued in solving this problem at home. In fact, unless we either present the public with actual information of this kind or make an actual impartial demonstration in one of our large cities, it would seem that the proper solution of the garbage question in this country will be still further postponed.

Mr. Ball makes an appeal for the disposal of street sweepings by burning instead of by filling in land, and offers many statements to support it. Such a disposition is made in several cities of Europe. In view of the fact that this material forms a rich field for disease germs, its incineration is certainly to be preferred when practicable. There are, however, many cases, particularly in our country, where the quota of combustible matter is reduced so greatly by admixture with mineral matter from badly paved or unpaved streets, that burning becomes expensive. In such cases filling in land is not only cheaper, but may be without sanitary danger. Mr. Ball further discusses the demolition of infected buildings, and gives the precautions which should be taken in their demolition. This subject had not before been touched upon, and is of sufficient importance to have been made a part of the subject under discussion. The writer believes Mr. Ball's precautions to be wise and practicable.

Commissioner Woodbury, by his remarks, leaves a doubt resting on the financial preference of the incineration over the reduction process, yet produces no facts to substantiate it. Mr. Parsons, on the other hand, unhesitatingly states his belief that incineration of the garbage of New York City is cheaper than its reduction, but, likewise, without substantiation. These, and other statements, confirm the opinion expressed by the writer, that experiments on a large scale, combined with an exhaustive inquiry into the subject, are required to demonstrate the best as well as the most economical disposal.

PROCEEDINGS

OF THE

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OF

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(INSTITUTED 1852.)

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APRIL, 1903.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

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INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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April 1st, 1903.—The meeting was called to order at 8.40 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary, and present, also, 119 members and 25 guests.

The minutes of the meetings of March 4th and 18th, 1903, were approved as printed in *Proceedings* for March, 1903.

A paper entitled "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E., was presented by the author and illustrated with lantern slides. The paper was discussed by Messrs. Allen Hazen, J. P. A. Maignen, Rudolph Hering, C. L. Harrison, J. Waldo Smith, R. S. Weston, George C. Whipple, William B. Fuller, L. L. Tribus and the author.

A paper entitled "Automatic Modules for Regulating the Speed of Filtration," by Charles Anthony, Jr., M. Am. Soc. C. E., was presented by title. On this paper there was no discussion.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Baxter Lamont Brown, St. Louis, Mo.
Albert Harlow Dakin, Jr., New York City.
Charles Morton Emmons, Beaver Falls, Pa.
Fred Eugene Foss, State College, Pa.
Owen Bert French, Washington, D. C.
Morris Knowles, Pittsburg, Pa.
Carl Gustaf Emil Larsson, Pencoyd, Pa.
Samuel Phillips Mitchell, Philadelphia, Pa.
Henry Tegmeyer Porter, Greenville, Pa.
Charles Lewis Potter, Memphis, Tenn.
Henry Rohwer, St. Louis, Mo.
Henry Bedinger Rust, Pueblo, Colo.
Clifford Stanley Sims, New York City.
Leonard Chase Wason, Brookline, Mass.
Robert Patterson Woods, Indianapolis, Ind.

As Associate Members.

William Hoyt Balch, Washington, D. C.
Edward Joseph Carney, New York City.
Allan Wadsworth Carpenter, Jersey Shore, Pa.
Charles Corwin Crew, Versailles, Mo.
James Laird de Vou, Philadelphia, Pa.
Benjamin Franklin, Philadelphia, Pa.
Morgan Dodge Hayes, Pittsburg, Pa.
William Hale Kimball, Davenport, Iowa.
Francis Mason, New York City.
Sergius Pavlovitch Maximoff, St. Petersburg, Russia.
George Soter Miller, Fishers Island, N. Y.
James Adolphus Omberg, Jr., Memphis, Tenn.
Clifford Moses Pritchard, Leavenworth, Kans.
John Cornelious Sesser, Kansas City, Mo.
Marshall Ney Shoemaker, Philadelphia, Pa.
James William Skelly, St. Louis, Mo.

The Secretary announced the election of the following candidates by the Board of Direction on March 31st, 1903:

As Juniors.

Mark Anthony Beltaire, Jr., New York City.
Edwin Merritt Holmes, Daiquiri, Cuba.
Augustus Kempkey, Jr., Oakland, Cal.
James Henry Miner, Fort Dodge, Iowa.

EGBERT JESSUP MOORE, Phœnixville, Pa.
GEORGE TILLEY SEABURY, New York City.
JAMES HAMPDEN SMALL, Jr., New York City.
HERBERT JOSEPH WILD, Portland, Me.

The Secretary announced the following deaths:

CHARLES ANDREWS KNOWLTON, elected Member October 2d, 1901; died March 2d, 1903.

ROBERT BLUM OLNEY, elected Junior January 3d, 1895; Associate Member September 5th, 1900; died March 19th, 1903.

WILLIAM JOHNSTON TAYLOR, elected Fellow May 10th, 1870; died March 25th, 1903.

Adjourned.

April 15th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary, and present also, 54 members and 8 visitors.

A paper entitled "An Investigation of the Properties of Brick Under Different Physical Conditions," by S. M. Turrill, Assoc. Am. Soc. C. E., was presented by the Secretary, who also read a communication on the subject from E. J. McCaustland, Assoc. M. Am. Soc. C. E.

The Secretary announced the death of WILLIAM WARREN CARD, elected Member September 5th, 1883; died April 4th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 31st, 1903.—8.40 P. M.—President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Craven, Croes, Davison, Knap, Kuichling, Pegram, Osgood, and Schneider.

The following resolution was passed:

"That in the future in any year the Collingwood Prize for Juniors is not awarded, a sum equal to the value of the Prize be appropriated for the purchase of books, photographs, or exhibits of American Engineering Works; such exhibits to be inscribed in a manner indicating their source; and that it be made the duty of the Library Committee to expend such funds."

The following gentlemen were added to the Local Committee of Arrangements for the Convention already announced:

J. C. GUILD, Chattanooga, Tenn.
GEORGE O. TENNEY, Spartanburg, S. C.
W. A. LELAND, Columbia, S. C.
NESBIT WINGFIELD, Augusta, Ga.
J. N. HAZLEHURST, Mobile, Ala.

The following resignations were accepted: Archibald Alexander Schenck, M. Am. Soc. C. E.; Walter Bruce Gormly, Jun. Am. Soc. C. E.

Applications were considered and other routine business transacted.

Eight candidates for admission as Junior were elected.*

Adjourned.

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* See page 128.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, May 6th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "A Small Rock-Fill Dam," by H. deB. Parsons, M. Am. Soc. C. E.; and "Deflection of Beams with Variable Moments of Inertia," by C. W. Hudson, M. Am. Soc. C. E. These papers were printed in *Proceedings* for March, 1903.

Wednesday, May 20th, 1903.—8.30 P. M.—At this meeting a paper, by D. M. Andrews, M. Am. Soc. C. E., entitled "The Economic Improvement of the Coosa and Alabama Rivers, in Georgia and Alabama," will be presented for discussion. This paper is printed in this number of *Proceedings*.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches for members to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention will be held at Asheville, N. C., June 9th, 10th, 11th and 12th, 1903.

A circular will soon be issued giving information as to arrangements, which are in the hands of the following Committees:

COMMITTEE OF THE BOARD OF DIRECTION.

J. JAMES R. CROES, *Chairman.*

GEORGE H. PEGRAM, CHAS. WARREN HUNT.

LOCAL COMMITTEE.

J. L. LUDLOW, *Chairman.*

WILLIAM CAIN,	J. IMBRIE MILLER,
WILBUR F. FOSTER,	WILLIAM MONCURE,
GEORGE W. FRANK,	J. A. MONTGOMERY,
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J. N. HAZLEHURST,	ARTHUR PEW,
W. B. W. HOWE,	GEORGE O. TENNEY,
W. A. LELAND,	NESBIT WINGFIELD.

TOPICS FOR INFORMAL DISCUSSION.

Topic No. 1. Timber Tests. (See statement in detail as to this subject, on page 133.)

Topic No. 2. Sewage Purification. (This subject will be presented by Rudolph Hering, M. Am. Soc. C. E.)

Topic No. 3. In the treatment of the Mississippi River, is the Levee Theory justified by Experience?

Topic No. 4. Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

Topic No. 5. What is the effect of Sea-Water upon Steel, and upon Steel and Concrete used in Combination, and is the use of Steel in Sea-Water admissible?

Topic No. 6. In view of the increasing weights of Rolling Stock, for what loadings should Railroad Bridges be designed?

Discussion on each of these subjects is invited. Communications from members who are unable to attend the Convention will be presented by the Secretary.

TIMBER TESTS.

This subject will be introduced for discussion at the Annual Convention by Gifford Pinchot, Assoc. Am. Soc. C. E., of the Bureau of Forestry, of the U. S. Department of Agriculture, who has prepared the following statement:

The Bureau of Forestry, of the United States Department of Agriculture, intends to resume the work of testing timber formerly carried on by the Division of Forestry during the years 1891–1896. A large portion of the groundwork covered by the proposed investigation is of interest to engineers, and it is the desire of the Bureau that the results obtained shall be of the greatest value to them. To this end it is hoped that those engineers interested in the application of timber to construction, will, in this discussion, offer suggestions and make criticisms which will aid the Bureau in planning this series of tests.

It is the intention of the Bureau to take up these tests in a thorough manner and devote whatever time may be necessary for the solution of the problems involved. It is expected that the plan of operation will be sufficiently complete, and the methods of tests so well chosen, that the data obtained may be accepted by all experts.

The following account of the proposed tests is of a very general nature. Those who are particularly interested can obtain a description of the proposed tests in greater detail on application to the Bureau of Forestry, Washington, D. C.

The Bureau aims at results of practical value, such as the values expressing the strength and stiffness of the principal merchantable species of timber of this country. Not only will this be done for timber now in use, but efforts will be directed to ascertaining the value for structural purposes of timbers at present not largely used, as, for example, the Western Hemlock and the Southern Gums. A thorough series of tests will be made of the timbers of the Pacific Slope, particularly the Red Fir, otherwise called Oregon Pine or Douglas Spruce, which is now finding its way in increasing quantities to eastern markets. If it should appear that the work done on the Southern Pines by the Division of Forestry during the years 1891–1896 has been sufficiently complete, the proposed tests will not cover these timbers.

Experimentation will be directed also in advance to the investigation of the effects of different factors of the testing processes on the results, such as speed of application of a load, method of moisture determination, the effect of moisture, and of volatile oils.

The investigation of the effect of technological operations, such as methods of kiln drying, methods of preserving timber, etc., will be undertaken.

In determining the values of the strength and stiffness of various merchantable timbers, tests will be made, both on timber collected from the market and on timber collected in the forest. Full-sized sticks, as

used in construction, will in all cases be tested under their appropriate loadings.

Work is at present in progress at a station in California, on the different merchantable grades of these full-sized timbers, such as bridge stringers and car sills collected on the market. The locality of origin of the timbers is determined, and a full description of each stick, as well as a series of photographs of all six sides, is made a matter of record. Full information of the physical and mechanical properties of the sticks under test will be obtained.

The investigation of the effect of various conditions of forest growth on the physical and mechanical properties of timber will be undertaken whenever the Bureau is thoroughly prepared for this work.

It is hoped that the discussion will take up the need of making timber tests from the standpoint of the engineer. Suggestions are invited as to those particular matters which at present most need investigation. It is also desired that discussion shall take place concerning the methods of performing the tests, particularly as to the best method of determining the moisture in timber; and the best method of determining the shearing strength of timber.

It is hoped that a full criticism of the former tests, both as to methods and content, will be given.

It is recognized that timber is subject to a great number of variables. From the botanical standpoint, the ideal method of procedure would be to determine the properties of the wood fiber of each species representing the normal growth of straight-grained timber. With these standard values as a basis, inquiries could be directed to ascertain how much the values are affected by such variables as moisture, oil, speed of test, imperfection of structure due to direction of grain or knots, rate of growth, diseases of the tree, technological processes such as kiln drying or preserving, etc.; forest conditions, region, and growth. It would seem that the interests of all, whether engineers, manufacturers, or botanists, would be consulted by such a method of procedure. The particular series of tests on full-sized sticks of market timber would form part of this general scheme.

ACCESSIONS TO THE LIBRARY.

From March 11th to April 7th, 1903.

DONATIONS.*

STORAGE BATTERY ENGINEERING.

A Practical Treatise for Engineers. By Lamar Lyndon, Assoc. M. Am. Inst. E. E. Cloth, 9½ x 6½ ins., 382 pp., illus. New York, McGraw Publishing Company, 1903. $3.00.

This book is intended to assist the practicing engineer in designing, installing and maintaining battery equipments, and to guide him in the selection of types of batteries and auxiliary apparatus best suited to the service which they are to perform, and at the same time impress upon the technical public, both the advantages and limitations of the storage battery in practice. Mathematics have been avoided as far as possible. The Osmotic and Thermodynamic theories of the storage battery have not been discussed, as their comprehension requires more electro-chemical knowledge than the majority of electrical engineers possess, and this work is intended to be a practical engineers' manual. The chapter headings are: General Theory of the Storage Battery; General Requirements; On Voltage and its Variation; On Quantity and Distribution of Active Material; On Electrolyte; On Quantity of Electrolyte; On Internal Discharge; On the Influence of Temperature; On Capacity Variation; On Internal Resistance; On Efficiency; On the Durability and Causes of Deterioration; On Diseases and their Remedies; On Care and Management; Types of Planté Plates; Methods of Planté Formation; Faure System; Applied Active Material Mixtures; Envelopes and Separators; Containing Cells; Assembling and Installing; Testing; Miscellaneous Data. There is an index of five pages.

SPECIFICATIONS FOR ELECTRIC RAILWAY BRIDGES. 1902.

By C. S. Davis. Paper, 9 x 6 ins., 8 + 48 pp. Toledo, C. S. Davis, 1902. 50 cents.

In these specifications an equivalent load has been used by the author for the reason that the wheel base and wheel loads for electric railway cars vary to such an extent that it seems a useless task to use a different wheel load and wheel base for every line. The equivalent load used is the same for any span length, and gives results reasonably close for any wheel base that is now being used. There are nine general divisions, as follows: General Description; Loads; Unit Stresses; Details of Design; Shop Work; Field Work; Quality of Material; Inspection; Maintenance.

HEATING AND VENTILATING BUILDINGS.

A Manual for Engineers and Architects. By Rolla C. Carpenter, M. Am. Soc. M. E. Fourth Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 16 + 562 pp., illus. New York, John Wiley & Sons, 1903. $4.00.

The present edition of this work has been very largely re-written and considerable new matter added, the size of the book, as compared with the first edition, being increased by nearly one-third. Three new chapters have been added: One relating to the fan or blower for moving air, another to the general subject of mechanical systems of heating and ventilating, and a third to schoolhouse heating and ventilation. It is believed that the book in its present form describes the latest improvements in the art of heating and ventilating. It also gives directions for the construction and installation of all the various sytems of heating and ventilating now in use. The Contents are: Nature and Properties of Heat; Principles of Ventilation; Amount of Heat Required for Warming; Heat Given off from Radiating Surfaces; Pipe and Fittings Used in Steam and Hot-Water Heating; Radiators and Heating Surfaces; Steam-Heating Boilers and Hot-Water Heaters: Settings and Appliances; Methods of Operating; Various Systems of Piping; Design of Steam and Hot-Water Systems; Heating with Exhaust Steam; Non-Gravity Return Systems; Heating with Hot Air; Mechanical Ventilators; Mechanical Systems of Heating and Ventilating; Heating with Electricity; Temperature Regulators; Schoolhouse Warming and Ventilation; Specification Proposals and Business Suggestions; Appendix. There is an index of twenty pages.

* Unless otherwise specified, books in this list have been donated by the Publishers.

DISINFECTION AND DISINFECTANTS.

A Practical Guide for Sanitarians, Health and Quarantine Officers. By M. J. Rosenau. Cloth, 8 x 6 ins., 353 pp., illus. Philadelphia, P. Blakiston's Son & Co., 1902. $2.00.

The preface states that this book has been written with the hope that it may help others who have to battle with the infection of the communicable diseases. The author has tried to set down the results of his experience gained in sanitary work of a public-health character, both in the field and in the laboratory. It has been his aim to state the important facts in a form to be of practical use to the disinfector. The subject has been considered from the standpoint of the disinfectant used, the object to be disinfected, and the disease for which the disinfection is done. In considering any subject from three points of view a certain amount of repetition is unavoidable. The chapter headings are: Introduction; Physical Agents; Gaseous Disinfectants; Chemical Solutions; Insecticides Applied to Disinfection Against the Insect-Borne Diseases; Disinfection of Houses, Ships and Objects; Disinfection for the Communicable Diseases. There is an index of seven pages.

THE ELECTRIC TELEPHONE.

By Edwin J. Houston and A. E. Kennelly. Second Edition, Enlarged. Cloth, 7 x 5 ins., 6 + 453 pp., illus. New York, Electrical World and Engineer, copyright 1902. $1.00. (Presented by the McGraw Publishing Co.)

The authors have prepared this little book on the telephone, in the hope of enabling those who are not trained in electro-technics to understand the main principles and method of operation of the telephone systems of to-day. Since the first edition much growth and development have taken place in telephonic engineering and practice. The authors have added three new chapters upon recent subjects of importance, and believe, that by so doing, the book will be brought up to date. The chapter headings are: Introductory; Elementary Acoustic Principles; The Telephone Receiver; The Microphone Transmitter; The Induction Coil; Call Bells and Batteries; Single-Circuit Connections; Multiple-Circuit Connections; Isolated-Station Switchboards; Multiple Switchboards; Telephonic Circuits; Long-Distance Telephony; Radiphony and Miscellaneous Applications of Electricity; Common-Battery Systems; Visual Signals; Loaded Telephone Circuits. There is an index of twenty-seven pages.

THE ART OF ILLUMINATION.

By Louis Bell. Cloth, 9 x 6 ins., 339 pp., illus. New York, McGraw Publishing Co., 1902. $2.50.

The author states in the preface that this volume is a study of the utilization of artificial light. It is intended to deal, not with the problem of distributing illuminants, but with their application, and treats of the illuminants themselves only in so far as a knowledge of their peculiarities is necessary to their intelligent use. To compress the subject within reasonable bounds, it has been necessary to discuss general principles rather than concrete examples of artificial lighting. The Contents are: Light and the Eye; Principles of Color; Reflection and Diffusion; The Materials of Illumination—Illuminants of Combustion; The Materials of Illumination—Incandescent Burners; The Electric Incandescent Lamp; The Electric Arc Lamp; Shades and Reflectors; Domestic Illumination; Lighting Large Interiors; Street and Exterior Illumination; Decorative and Scenic Illumination; The Illumination of the Future; Standards of Light and Photometry. There is an index of five pages.

RAILROAD CONSTRUCTION, THEORY AND PRACTICE.

A Text-Book for the Use of Students in Colleges and Technical Schools. By Walter Loring Webb, Assoc. M. Am. Soc. C. E. Second Edition, Revised and Enlarged. Morocco, 7 x 4 ins., 17 + 675 pp., illus. New York, John Wiley & Sons, 1903. $5.00.

The preface states that the inconvenience of the octavo edition for field-work was found to be limiting the use of the book. It was therefore decided to recast the whole work and reduce the page from "octavo" to "pocket-book" size. Advantage was then taken of the opportunity to revise freely and to add new matter. The author's primary aim has been to produce a text-book for students, the subject-matter has therefore been cut down to that which may properly be required of students in the time usually allotted to railroad work in a civil-engineering curriculum. On this account no extended discussion has been given to the multitudinous forms of various

railroad devices in the chapters on structures. The aim has been to teach the principles and to guide the students into proper methods of investigation. The Contents are: Railroad Surveys; Alignment; Earthwork; Trestles; Tunnels; Culverts and Minor Bridges; Ballast; Ties and Other Forms of Rail Support; Rails; Rail-Fastenings; Switches and Crossings; Miscellaneous Structures and Buildings; Yards and Terminals; Block Signaling; Rolling Stock; Train Resistance; Cost of Railroads; The Promotion of Railroad Projects; Operating Expenses; Distance; Curvature; Grade; Improvement of Old Lines; Adjustments of Instruments. There is an index of twenty-three pages.

BLACKWELL'S ISLAND BRIDGE IN THE CITY OF NEW YORK.

By Gustav Lindenthal. Paper, 24 x 15 ins., 6 plates. New York, 1903. 60 cents. (Donated by the author.)

SELF-PROPELLED VEHICLES.

A Practical Treatise on the Theory, Construction, Operation, Care and Management of All Forms of Automobiles. By James E. Homans. Cloth, 9 x 6 ins., 6 + 626 pp., illus. New York, Theo. Audel & Company, 1902. $2.00.

The preface states that the treatment of subjects throughout this work has been kept as nearly as possible in the lines popularly called "non-technical," and the various theories and problems involved in the construction and operation of the prevailing types of motor road carriages have been stated as clearly and simply as possible, in order that the involved situations may be readily comprehended by all readers. The fundamental principles of the several types of motor, particularly of the gasoline engine, have been treated at considerable length, in order that the facts may be comprehended in their new relations. It has been the author's aim to state and discuss the most important points of this already immense subject, and to treat only of constructions that have been proven thoroughly practical. There is an index of six pages.

A PHILOSOPHICAL ESSAY ON PROBABILITIES.

By Pierre Simon, Marquis de Laplace. Translated from the Sixth French Edition by Frederick Wilson Truscott and Frederick Lincoln Emory, M. Am. Soc. M. E. Cloth, 8 x 5 ins., 4 + 196 pp. New York, John Wiley & Sons, 1902. $2.00.

This essay is the development of a lecture on probabilities which the author delivered in 1795 to the normal schools whither he had been called, by a decree of the national convention, as professor of mathematics, with Lagrange. The author presents here, without the aid of analysis, the principles and general results of the theory of probabilities, applying them to the most important questions of life.

Gifts have also been received from the following:

Am. Inst. of Min. Engrs. 17 pam.
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U. S. Bureau of Statistics. 1 bound vol.
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Western Ry. Club. 1 bound vol.

BY PURCHASE.

Die Gleichstrommaschine, Theorie, Konstruktion, Berechnung, Untersuchung und Arbeitsweise derselben. Von E. Arnold. Vol. I. Berlin, Julius Springer, 1902.

Hydraulic Power and Hydraulic Machinery. By Henry Robinson, M. Inst. C. E., M. I. M. E. Second Edition, Revised and Enlarged. London, Charles Griffin and Company, Limited, 1893.

The Balancing of Engines. By W. E. Dalby, M. Inst. C. E., M. I. M. E. New York, Longmans, Green and Co.; London, Edward Arnold, 1902.

The Steam Turbine. By Robert M. Neilson, Assoc. M. I. M. E. Longmans, Green and Co., London, New York and Bombay, 1902.

The Thermodynamics of Heat-Engines. By Sidney A. Reeve. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1903.

Die Geschichte des Eisens in technischer und kulturgeschichtlicher Beziehung. Von Dr. Ludwig Beck. Vol. V, Pt. 8. Braunschweig, Friedrich Vieweg, 1903.

Rand, McNally & Co.'s Indexed Atlas of the World. Historical–Descriptive–Statistical. 2 vol. Rand, McNally & Company, Chicago, New York, London, Berlin, copyright 1902.

The New Volumes of the Encyclopædia Britannica, constituting, in combination with the existing Volumes of the Ninth Edition, the Tenth Edition of that Work, and also Supplying a New, Distinctive, and Independent Library of Reference Dealing with Recent Events and Developments. Vols. I to VII, Forming Vols. XXV to XXXI of the Complete Work. Adam and Charles Black, London and Edinburgh, The Encyclopædia Britannica Company, New York, 1902.

Controle des Chemin de Fer et des Tramways. Par Jean de la Ruelle. Paris, Vve. Ch. Dunod, 1903.

The Trans-Siberian Route; or, Notes of a Journey from Peking to New York in 1902. By Clarence Cary. New York, The Evening Post Job Printing House, 1902.

Tracé et Terrassements. Tracé par P. Frick; Terrassements par J. L. Canaud. Paris, Vve. Ch. Dunod, 1903.

Calcareous Cements: Their Nature and Uses, with some Observations upon Cement Testing. By Gilbert R. Redgrave, Assoc. Inst. C. E. London, Charles Griffin and Company, Limited, 1895.

Slow Burning or Mill Construction. Report No. V of the Insurance Engineering Experiment Station. Boston, 1902.

SUMMARY OF ACCESSIONS.

From March 11th to April 7th, 1903.

Donations (including 355 duplicates)	886
By purchase	20
Total	906

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
Brown, Baxter Lamont. Chf. Engr., St. L. Val. Ry., Room 72, Laclede Bldg., St. Louis, Mo.		April 1, 1903
Dakin, Albert Harlow, Jr. Asst. Engr., C. R. R. of N. J., 370 St. Nicholas Ave., New York City.		April 1, 1903
Eno, Frank Harvey. Assoc. Prof. of Civ. Eng., Hayes Hall, Ohio State Univ., Columbus, Ohio.		Mar. 4, 1903
Finley, William Henry. Prin. Asst. Engr., C. & N. Ry., Winnetka, Ill.		Feb. 4, 1903
Foss, Fred Eugene. Prof. of Civ. Eng., Pennsylvania State Coll., State College, Pa.		April 1, 1903
Knowles, Morris. Filtration Engr., City of Pittsburg; Civ. and Cons. Engr. (Chapin & Knowles), 1017 Frick Bldg., Pittsburg, Pa.	Jun. Assoc. M. M.	Oct. 4, 1892 Jan. 1, 1896 April 1, 1903
Porter, Henry Tegmeyer. Chf. Engr., Pitts., Bessemer & L. E. R. R. and West. Allegheny R. R., Greenville, Pa.		April 1, 1903
Sims, Clifford Stanley. Gen. Supt., B. & O. R. R., N. Y., Ft. of Whitehall St., New York City.		April 1, 1903
Woods, Robert Patterson. Chf. Engr., Townsend, Reed & Co., Ry. Builders, 1208 Stevenson Bldg., Indianapolis, Ind.	Jun. Assoc. M. M.	Feb. 2, 1897 Mar. 7, 1900 April 1, 1903

ASSOCIATE MEMBERS.

Balch, William Hoyt. Engr., Southern Expanded Metal Co., 1237 G St., N. W., Washington, D. C.		April 1, 1903
Carney, Edward Joseph. Dept. of Bridges, 19 Park Row (Res., 527 West End Ave.), New York City.	Jun. Assoc. M.	Feb. 1, 1898 April 1, 1903
Mason, Francis. Care, Penn., N. Y. & L. I. R. R., 225 West 33d St., New York City.	Jun. Assoc. M.	April 3, 1900 April 1, 1903
Mattair, Lewis Henry. Custom House, Chattanooga, Tenn.		Oct. 1, 1902
Shima, Takejiro. Imperial Government Ry., Shinbashi, Tokio, Japan.		Mar. 4, 1903
Shoemaker, Marshall Ney. Vice-Pres. and Phila. Mgr., Am. Concrete-Steel Co. (Res., 7236 Ridge Ave., Roxborough), Philadelphia, Pa.		April 1, 1903

JUNIORS.

Clausnitzer, John. Engr. Insp., Dept. of Highways, Brooklyn, 157 East 21st St., New York City.		Mar. 3, 1903
Harps, Harry Macy. Asst. Bridge Engr., Mason City & Fort Dodge R. R., Fort Dodge, Iowa.		Mar. 3, 1903

	Date of Membership.
MATHESON, JOHN DOUGLAS. 67 West 133d St., New York City	Mar. 3, 1903
MINER, JAMES HENRY. Box 99, Fort Dodge, Iowa	Mar. 31, 1903
SEABURY, GEORGE TILLEY. Asst. Engr., Rapid Transit Subway Constr. Co., 1913 Amsterdam Ave., New York City	Mar. 31, 1903
TRUE, ALBERT LYMAN. The Owl's Nest, Cape Cottage, Me	Sept. 2, 1902
WHITMAN, EZRA BAILEY. 702 Fuller Bldg., New York City	Feb. 3, 1903

CHANGES OF ADDRESS.

MEMBERS.

ASSERSON, PETER CHRISTIAN.....Rear Admiral and Civ. Engr., U. S. N., 1517 Rhode Island Ave., Washington, D. C.

BILLIN, CHARLES EMERY.....205 Goethe St., Chicago, Ill.

BLACK, WILLIAM MURRAY.....Maj., Corps of Engrs., U. S. A., Care, Isthmian Canal Comm., Corcoran Bldg., Washington, D. C.

BURKE, MILO DARWIN.....Room 18, N. E. cor. Fourth and Walnut Sts., Cincinnati, Ohio.

CAPPELEN, FREDERICK WILLIAM.....Cons. Engr., 610 Globe Bldg., Minneapolis, Minn.

COOMBS, STEPHEN ELBRIDGE.....Room 512, Grand Central Station, New York City.

DAVIS, CHANDLER.....11 West 34th St., New York City.

DILLMAN, GEORGE LINCOLN.....328 Montgomery St., San Francisco, Cal.

FITCH, CHARLES HALL.....Engr., U. S Geological Survey, 3062 Q St., N. W., Washington, D. C.

HARLEY, ALFRED FRANCIS.....Mandarin, Fla.

HITCHCOCK, FREDERICK COLLAMORE.....Care, Geo. S. Good & Co., Room 27, Railroad Bldg., Denver, Colo.

JOHNSON, LUCIEN SAMUEL.....Jun. Engr., U. S. Engr. Dept., Louisa, Lawrence Co., Ky.

KELLER, CHARLES.....Capt., Corps. of Engrs., U. S. A., Manila, Philippine Islands.

LOWRIE, HARVEY CHILDS.....Pres., The Lowrie Safe & Lock Co., 1106 Fuller Bldg., Fifth Ave. and Broadway, New York City.

LUSK, JAMES LORING.....Maj., Corps of Engrs., U. S. A., U. S. Engr. Office, Rock Island, Ill.

MCCORMICK, GEORGE KING.....Roadmaster, A., K. & N. Ry., Blue Ridge, Ga.

MAXIM, HIRAM STEVENS.....Care, Reginald Crosse, 7 Lancaster Pl., Strand, London, England.

MORSE, CHARLES ADELBERT.....Engr. of Eastern Grand Div., A., T. & S. F. Ry., Topeka, Kans.
MORSE, EDWIN KIRTLAND.....Farmers National Bank Bldg., Pittsburg, Pa.
RICHARDSON, B. FRANK.....11th Ave. and 184th St., New York City.
STEVENS, JOHN FRANK.....Chf. Engr., C., R. I. & P. Ry., Chicago, Ill.
STURTEVANT, CARLETON WILLIAM.....Engr. with the Atlantic, Gulf & Pacific Co., Box 607, Mobile, Ala.
TOWL, FORREST MILTON.....Rialto Bldg., San Francisco, Cal.
WADDELL, ROBERT WILLIAM.....720 Delaware St., Room 401, Kansas City, Mo.
WOERMANN, JOHN WILLIAM.....U. S. Asst. Engr., Waterway from Chicago to St. Louis, 1115 N. Monroe St., Peoria, Ill.
YORK, HERBERT WALDO.....Chf. Engr., Am. Smelting & Refining Co., 71 Broadway, New York City.

ASSOCIATE MEMBERS.

BALDWIN, HIRAM ELLSWORTH.....32 Earle Ave., Glenville, Ohio.
COLLIER, BYRAN CHEVES.....Asst. Engr., Dept. of Highways (Res., 2721 Bainbridge Ave., Bedford Park), New York City.
COLLINS, CLARKE PELEG.....Gen. Mgr. and Chf. Engr., Kimberly Run Coal Co., Somerset, Pa.
COWPER, JOHN WHITFIELD.....London Mgr., James Stewart & Co., Engrs. and Contrs., Savoy Hotel, Strand, London, W. C., England.
GREGORY, JOHN HERBERT.....Asst. Engr., Comm. on Additional Water Supply, 2023 Park Row Bldg., New York City.
HAIN, JAMES C.....Engr., Masonry Constr., C., M. & St. P. Ry. Co., 192 Fullerton Ave., Chicago, Ill.
HAMMATT, WILLIAM CUSHING.....Eng. Dept., N. Y. C. & H. R. R. R., New York City.
HASTINGS, FRANK ARNOLD.....Eng. Dept., Am. Bridge Co., 51st and Butler Sts. (Res., 7 Mawhinney St.), Pittsburg, Pa.
HOFFMANN, ROBERT.....P. O. Box 180, Cleveland, Ohio.
HOLMES, GLENN DICKINSON.....Asst. Engr., New York Water Supply Comm., Room 1819, Park Row Bldg., New York City.
LOCKWOOD, WILLARD DATUS.....Care, Frodingham, Iron & Steel Works, Frodingham, near Doncaster, England.

LUND, GEORGE ALFRED.....6 Church Sq., Capetown, South Africa.
MCGEE, VAN NORMAN.....405 Taber Opera House Blk., Denver, Colo.
PARSONS, ARCHIBALD LIVINGSTONE.....Civ. Engr., U. S. N., Mare Island Navy Yard, Cal.
ROWELL, GEORGE FREEMAN.....Asst. Engr., Susquehanna Canal & Power Co., 1402 Continental Trust Bldg., Baltimore, Md.
STEFFENS, WILLIAM FREDERICK.....Care, A. T. Hardin, Engr., M. of W., N. Y. C. & H. R. R. R., 5 Vanderbilt Ave., New York City.
TROUT, CHARLES ELIPHALET.....West New Brighton, N. Y.
WAITE, GUY BENNETT.....Civ. Engr. and Contr., 352 West 115th St., New York City.
WILSON, EVERETT BROOMALL.....78 Elm Ave., Rahway, N. J.

ASSOCIATES.

BOOTH, WILLIAM FERRIS.....42 Market St., Poughkeepsie, N. Y.
QUINCY, CHARLES FREDERICK.....Vice Pres., Railway Appliances Co., Old Colony Bldg., Chicago, Ill.

JUNIORS.

BASSETT, ROBERT JAY.....110 East 50th St., New York City.
BELCHER, WALLACE EDWARD.....Niagara Falls Power Co., Niagara Falls, N. Y.
BELZNER, THEODORE.....Insp., Rapid Transit R. R. Comm., Sec. 3, 1st Div., 13 Astor Pl. (Res., 584 Lenox Ave.), New York City.
CLEAVER, PITSON JAY.....445 Fifty-fifth St., Brooklyn, N. Y.
DAY, ARTHUR MORTIMER.....149 West 44th St., New York City.
HENLEY, ROBERT DWIGGINS MONTEITH.....Asst. Engr., L. & N. R. R., Pensacola, Fla.
HYATT, CALEB.....Pulver House, Ravena, N. Y.
MILLARD, CURTISS.....Pres. and Gen. Mgr., Peoria & Pekin Union Ry. Co., Peoria, Ill.
MORPHY, LUIS GONZAGA.....Asst. Engr., N. Y. C. & H. R. R. R., 5 Vanderbilt Ave., New York City.
PAINE, GEORGE HEBARD.....Cons. Engr., 83 Fulton St., New York City.
PERRING, HENRY GARFIELD.....Draftsman, Phil. Rap. Trans. Co., 134 North 50th St., Philadelphia, Pa.
WENIGE, ARTHUR EMIL.....Care, Bureau of Eng., Finance Dept., 280 Broadway, New York City.
WHITTED, LEVI ROMULUS.....Navy Yard, Charleston, S. C.

RESIGNATIONS.

MEMBERS.

	Date of Resignation.
SCHENCK, ARCHIBALD ALEXANDER	March 31st, 1903

JUNIORS.

GORMLY, WALTER BRUCE	March 1st, 1903

DEATHS.

KNOWLTON, CHARLES ANDREWS.....Elected Member, October 2d, 1901; died March 2d, 1903.

OLNEY, ROBERT BLUM.....Elected Junior, January 3d, 1895; Associate Member, September 5th, 1900; died March 4th, 1903.

TAYLOR, WILLIAM JOHNSTON.....Elected Fellow, May 10th, 1870; died Feb. 17th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(March 11th to April 7th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

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Report of Special Commission of Engineers on the Plans for the Manhattan Bridge, New York City. (13) Mar 12; (14) Mar. 21.
A Railway Trestle with Bents of Reinforced Concrete.* Wm. A. Allen, Assoc. M. Am. Soc. C. E. (13) Mar. 12.
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An Automatic Telephone Operator. William J. Hammer. (42) Feb.
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Radiant Efficiency of the Mercury Arc. (27) Feb. 28.
Analysis of the Seventh Annual Report of the Public Lighting Commission, Detroit, Mich. (27) Feb. 28.
A Study of the Phenomenon of Resonance in Electric Circuits by the Aid of Oscillograms. M. B. Field. (Abstract of paper read before the Glasgow Section, Inst. Elec. Engrs.) (26) Serial beginning Mar. 6.
The Joint Transmission of Differing Currents. Frederick Bedell. (Abstract of paper read before the Elec. Soc. of Cornell Univ.) (26) Mar. 6.
The Electric Lighting of Eastbourne.* (26) Mar. 13.
Some Notes on Continental Power House Equipment. H. L. Riseley, A. M. I. E. E. (Abstract of paper read before the Newcastle Local Section, Inst. Elec. Engrs.) (26) Mar. 13.
The 22000-Volt Transmission Installation of the Northern California Power Company.* (27) Mar. 14.
Electricity as a Motive Power in Mechanical Flight.* T. Byard Collins. (27) Mar. 14.
The Heyland Induction Motor. Boy de la Tour. (27) Serial beginning Mar. 14.
High Temperature Electro-Chemistry: Notes on Experimental and Technical Electric Furnaces.* R. S. Hutton, A. I. E. E., and J. E. Petavel, A. M. I. E. E. (Paper read before the Inst. of Elec. Engrs.) (19) Serial beginning Mar. 14.
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A Notable Invention in Rapid Telegraphy. Romyn Hitchcock. (27) Mar. 21.
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The Development and Use of the Small Electric Motor.* Fred. M. Kimball. (9) Apr.
Alternating Current for Light and Power. Chas. F. Scott, Pres. Am. Inst. E. E. (10) Apr.
Electrical Developments in Russia.* Thomas E. Heenan. (10) Apr.
Power Test of an Electrically-Driven Shaper.* (25) Apr.
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Notes on the Design of Riveter Yokes.* Chester B. Albree. (58) Jan.
The Theory of Operation of the Gasoline Engine.* E. C. Oliver. (1) Feb.
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Hydraulic Experiments on a Plunger Pump.* John Goodman. (Paper read before the Inst. of Mech. Engrs.) (62) Serial beginning Mar. 19.
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Les Condensations Centrales.* A. Abraham. (36) Serial beginning Feb. 25.
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Railroad Shop Tools. Charles H. Fritch. (39) Serial beginning Apr.
Electric Traction on Steam Railways. Alton D. Adams. (10) Apr.
The Application of Individual Motor Drives to Old Machine Tools; McKees Rocks Shops, Pittsburg & Lake Erie R. R.* R. V. Wright. (25) Serial beginning Apr.
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Improved Treatment of Cast Iron Car Wheels. F. E. Seeley. (25) Apr.

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Tunnel at Michel Creek Loop, Crow's Nest Pass Line, Canadian Pacific Ry.* C. R. Coutlee, M. Can. Soc. C. E. (13) Apr. 2.

The Safe Course (for Prevention of Collisions). Charles Hansel, M. Am. Soc. C. E. (13) Apr. 2.

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THE ECONOMIC IMPROVEMENT OF THE COOSA AND ALABAMA RIVERS, IN GEORGIA AND ALABAMA.

By D. M. Andrews, M. Am. Soc. C. E.

To be Presented May 20th, 1903.

The Coosa River is formed by the junction of the Oostanaula and Etowah Rivers at Rome, Ga., which streams have their sources in the mountains of Northern Georgia.

The Oostanaula and its tributary, the Coosawattee, are navigable the year round for light-draft boats from Rome, Ga., to Carter's Landing, a distance of 105 miles.

The Coosa has always been navigable from Rome, Ga., to Greensport, Ala., a distance of 162 miles. From Greensport to Lock No. 4, Ala., a distance of 26 miles, the river has been made navigable for boats of 4-ft. draft by the construction of three locks and four dams, and by channel excavation at points between the dams. From Lock No. 4 to Wetumpka, Ala., a distance of 116 miles, there occurs a succession of rapids having a combined fall of 123 ft. In this section no work of improvement has been done, except at Wetumpka, where the

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

masonry of Lock No. 31 has been finished and a lock-master's house built. From Wetumpka to the mouth of the Coosa, a distance of 14 miles, the fall is gentle, and no locks and dams will be required. From Wetumpka to Mobile, Ala., a distance of 377 miles, there has always existed navigation for light-draft boats the year round.

It will thus be seen that on this system of rivers there would be, with the improvement of the 116 miles now closed to navigation, a water route of transportation from the mountains of Georgia to the Gulf, at Mobile, a distance of 786 miles.

The Coosa and Alabama Rivers were discovered by DeSoto in 1540. He marched down the entire length of the Coosa, and down the Alabama to the Choctaw Bluff, where, in an engagement with the tribe of Mobile Indians, his force was greatly weakened, though he almost annihilated the tribe of Indians.

After DeSoto's glimpse of them, these rivers almost disappeared from the knowledge of civilized man for nearly a century and a half. The words of Mark Twain, referring to the discovery of the Mississippi by the same explorer, apply equally well to the Coosa and Alabama Rivers:

"Apparently nobody happened to want such a river; nobody needed it, nobody was curious about it; so, for a century and a half, the Mississippi remained out of the market and undisturbed. When DeSoto found it, he was not hunting for a river, and had no present occasion for one, consequently, he did not value it or even take any particular notice of it."

Geologically, the Coosa flows through the formations of the Paleozoic Era to within 27 miles of Wetumpka. Through this last part of its course it flows over crystalline rocks of pre-Cambrian origin, and at Wetumpka enters the coastal plain and the Cretaceous formation.

Through its upper course the river passes through the Coosa coal field near Lock No. 4, and, in places, the bluffs forming its banks contain great deposits of iron ore and limestone. In this section occur also deposits of bauxite, roofing slates, and great forests of long-leaf (Southern) pine and hard woods of many varieties.

The drainage area of the Coosa Basin, to Riverside, Ala., 113 miles above Wetumpka, including its tributaries, is given by the Hydrographic Division of the United States Geological Survey at 6 850 sq. miles.

The country adjacent to the Alabama River, while rich, agriculturally, has few, if any, mineral resources.

The banks of the Coosa, over the 116 miles to be improved, are generally high, and in many places they are precipitous, rocky bluffs. On such a stream, then, high lifts for locks and dams could be used without submerging much of the adjoining lands.

The questions now arise: First, what is the economic depth? and, second, what is the economic lift? Upon the correct answers to these two questions depends the proper solution of the problem, and in answering them the effort will be made to reduce the problem to the economic basis of business principles; the principles that govern the location of railroads, and the inauguration and construction of other works of a public character.

Two depths for the navigation of these rivers have been proposed namely, 4 ft. and 6 ft. The present discussion, therefore, will be confined to these two depths, for to extend it to others would carry the paper far beyond the limits proposed.

Acting under the direction of Captain R. R. Raymond, Corps of Engineers, U. S. A., the writer has deduced two equations, showing the relations between lift and cost of locks and accessories of standard design for the Coosa River, one for 4-ft. and one for 6 ft. navigation. The equations, the method of their deduction, and the theoretic economic effect of the use of the economic lifts are given in what follows, together with a discussion of other economic questions relating to the improvement.

Assuming the river to have a uniform slope and cross-section, the cost of one lock can be stated as follows:

Y = cost of one lock and accessories, in terms of the lift, = C + cost of excavation + cost of lock-walls + cost of wing-walls + cost of gates + cost of valves + cost of dam + cost of abutment + cost of guide piers + cost of engineering, inspection and office expenses.

The constant, C, includes:

Gate-maneuvering machinery	$410
Coffer-dam	5 000
Lock house	3 000
Fencing and outbuildings	1 500
Lock site	1 000
Miter-sills	1 206
	$12 116

The expression for the variable costs entering the equation, in which x, the lift, is a factor, are as follows:

Cost of excavation =

$$\left(\frac{x + m + d + e + w}{10}\right) l\, e$$

Cost of walls =

$$\tfrac{7}{27}\left[\left(k + \frac{m + x + d + e}{2}\right)\left(\frac{m + x + d + e}{2}\right) 2\, l + \left(\frac{m + x + d + e}{2} - k\right)(m + x + d + e)\, l''\right]$$

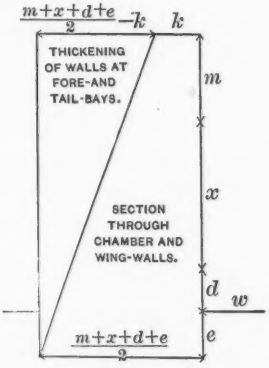


FIG. 1.

Cost of wing-walls =

$$\tfrac{7}{27}\left(k + \frac{m + x + d + e}{2}\right)\left(\frac{m + x + d + e}{2}\right) l'''$$

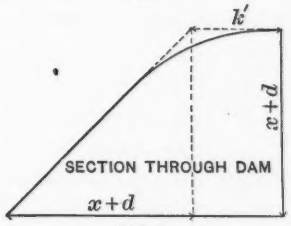


FIG. 2

Cost of gates =

$$4\, s\, (m + x + d)\, \sqrt{\tfrac{5}{16}\, w^2}$$

Cost of valves $= s'\left(\frac{4\, A\, \sqrt{x}}{+ c\, \sqrt{2\, g}}\right)$

Cost of dam =

$$\tfrac{1}{9}\, l'\left[(2\, k' + x + d)\left(\frac{x + d}{2}\right)\right]$$



PLAN OF GATES

FIG. 3.

Cost of abutment $= \tfrac{3}{27}\left[p\,(2\,x + 2\,d + 2\,k' + n)\left(\frac{x + d + n}{2}\right) + \tfrac{1}{3}\left(\frac{x + d + n}{2}\right)^2\left(2\,x + 2\,d + n\right) + \left(\frac{x + d + n}{2} + v\right)(x + d + n)\, k'\right]$

Cost of guide piers $= 300\, x$.

Cost of engineering, inspection, etc., $= 1\,500\, x$.

The values given the letters are the respective dimensions, etc., proposed for the locks, dams, etc., except the length of the dams, which is assumed. Unit prices are based upon the cost of similar work on this and the Warrior River.

l = length of lock, over all = 400 ft.;
m = guard of lock-walls = 8 ft.;
w = width of lock-chamber = 52 ft.;
k = width of lock and wing-wall coping = 4 ft.;
d = depth of water over miter-sills = 4 and 6 ft.;
s = cost per square foot of gate = \$3.81;
s' = cost per square foot of valve = \$15.59;
A = area of lock-chamber = 16 744 sq. ft.;
t = 360 seconds of time;
c = 0.635, determined from experiments at Lock No. 3, Coosa River;
k' = width of crest of dams = 8 ft.;
l' = average length of dams = 800 ft.;
p = width of abutment coping = 4 ft.;
n = guard of abutment = 14 ft.;
v = length of abutment stem = 10 ft.;
l'' = half length of heavy walls at fore- and tail-bays = 140 ft.;
l''' = length of wing-walls = 100 ft.;
e = depth of excavation = 4 ft.;
g = acceleration due to gravity = 32.2;

Substituting these values in the foregoing equations, and making $d = 4$, we get for 4-ft. navigation:

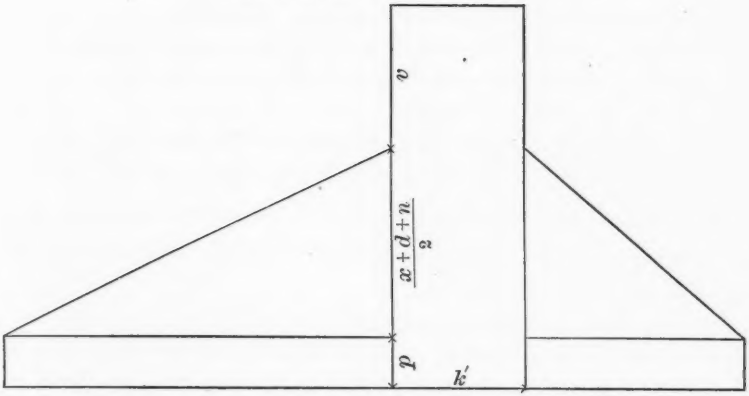
C = \$12 116.00;
Cost of excavation = \$10 880 + $160x$;
Cost of lock-walls = \$22 234.07 + 2 509.62x + $70x^2$;
Cost of wing-walls = \$2 488.88 + 259.26x + $6.48x^2$;
Cost of gates = \$5 316.32 + 443.03x;
Cost of valves = \$569.19$\sqrt{x}$;
Cost of dam = \$3 555.55 + 1 066.67x + $44.44x^2$;
Cost of guide piers = \$300x;
Cost of engineering, inspection, etc., = \$1 500x;
Cost of abutment = \$1 403.85 + 145.78x + $4.69x^2$ + $0.0494x^3$.

And Y = \$57 994.67 + 569.19$\sqrt{x}$ + 6 384.36x + $125.61x^2$ + $0.0494x^3$ ..... (1)

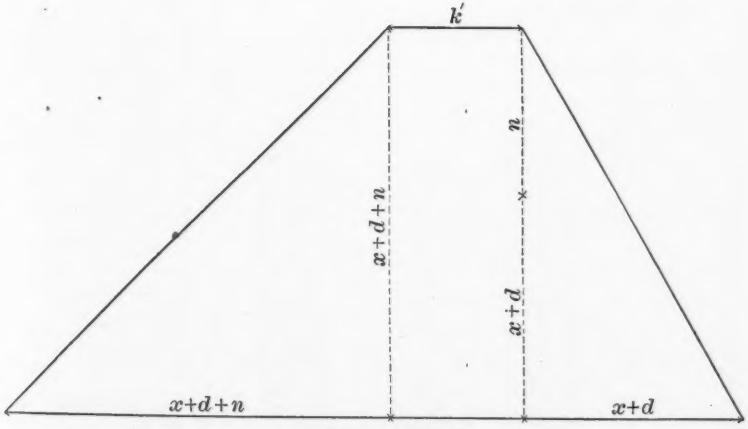
Again, substituting in the equations the values of the letters, and making $d = 6$, we get, for 6-ft. navigation:

C = \$12 116.00:
Cost of excavation = \$11 200 + $160x$;
Cost of lock-walls = \$27 533.33 + 2 789.63x + $70x^2$;

SKETCH OF ABUTMENT.



PLAN.



FRONT ELEVATION.

FIG. 4.

Cost of wing-walls $= \$3\,033.33 + 285.19x + 6.48x^2$;

Cost of gates $= \$6\,202.38 + 443.03x$;

Cost of valves $= \$569.19\sqrt{x}$;

Cost of dam $= \$5\,866.67 + 1\,244.44x + 44.44x^2$;

Cost of guide piers $= \$300x$;

Cost of engineering, inspection, etc., $= \$1\,500x$;

Cost of abutment $= \$1\,702.72 + 165.13x + 4.99x^2 + 0.9494x^3$,

And $Y = \$67\,654.43 + 569.19\sqrt{x} + 6\,887.42x + 125.91x^2 + 0.0494x^3$.. ..... (2)

The fall from the upper pool at Lock No. 31 to the lower pool at Lock No. 4 is 309 ft. Let the number of locks required, with any lift, x, to overcome this fall $= N$; then $N = \frac{309}{x}$, and the cost of the improvement, exclusive of levees and overflowed lands, the cost of which is at present unknown, is $Y \times N$.

Tables Nos. 1 and 2 give the values of Y and N, and the total cost of the improvement, for every value of x, increasing by increments of 1 ft. from 5 to 30 ft., inclusive, for both 4-ft. and 6-ft. navigation. The curves in Fig. 5 show graphically the costs given in the tables.

TABLE No. 1.—VALUES OF Y AND N, AND TOTAL COST OF THE IMPROVEMENT FOR EVERY VALUE OF x, INCREASING BY INCREMENTS OF 1 FOOT FROM 5 TO 30 FEET.

FOR 4-FOOT NAVIGATION.

x, in feet.	Y.	N.	$Y \times N$. Costs of system.	
5.....	$94 334.38	61.8	$5 829 865	
6.....	102 227.70	51.5	5 264 727	
7.....	110 362.94	44.1	4 867 006	
8.....	118 743.81	38.6	4 583 512	
9.....	127 371.89	34.3	4 368 786	
10.....	136 247.31	30.9	4 210 042	
11.....	145 375.02	28.1	4 085 038	
12.....	154 751.92	25.75	3 984 862	
13.....	164 380.24	23.77	3 907 318	
14.....	174 260.53	22.07	3 845 930	
15.....	184 393.53	20.6	3 798 507	
16.....	194 779.70	19.31	3 761 196	
17.....	205 419.54	18.17	3 732 473	
18.....	216 313.78	17.17	3 714 108	
19.....	227 462.59	16.27	3 700 816	
20.....	238 866.56	15.45	3 690 488	
21.....	250 526.10	14.7143	3 686 316	21.5 ft. economical lift.
22.....	262 441.59	14.05	3 687 304	$3 685 751. $N = 14.3721$.
23.....	274 613.44	13.435	3 689 432	
24.....	287 042.01	12.87	3 694 233	
25.....	299 727.74	12.36	3 704 635	
26.....	312 670.92	11.88	3 714 531	
27.....	325 872.05	11.44	3 727 976	
28.....	339 331.34	11.04	3 746 218	
29.....	353 049.16	10.65	3 759 974	
30.....	367 025.89	10.30	3 780 367	

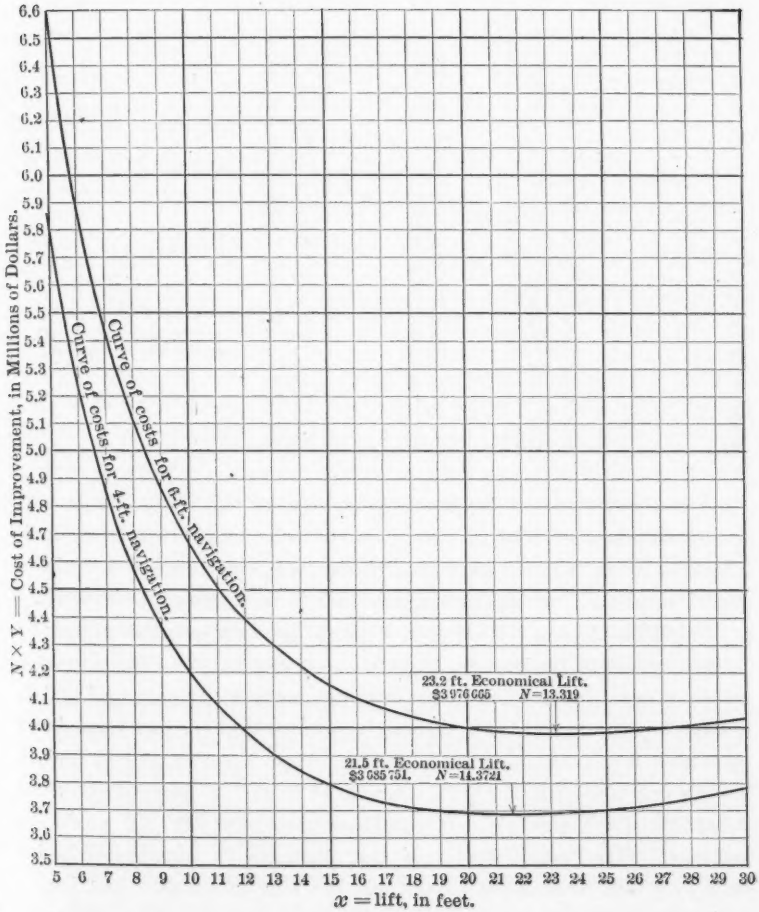

6.6
6.5
6.4
6.3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
$N \times Y$ = Cost of Improvement, in Millions of Dollars.
Curve of costs for 6-ft. navigation.
Curve of costs for 4-ft. navigation.
23.2 ft. Economical Lift.
$3 976 665 N=13.319
21.5 ft. Economical Lift.
$3 685 751. N=14.3721
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
x = lift, in feet.

FIG. 5.

TABLE No. 2.—VALUES OF Y AND N, AND TOTAL COST OF THE IMPROVEMENT FOR EVERY VALUE OF x, INCREASING BY INCREMENTS OF 1 FOOT FROM 5 TO 30 FEET.

FOR 6-FOOT NAVIGATION.

x, in feet.	Y.	N.	$Y \times N$. Costs of system.	
5	$106 518.21	61.8	$6 582 825	
6	114 916.61	51.5	5 918 205	
7	123 558.84	44.1	5 448 945	
8	132 447.24	38.6	5 112 463	
9	141 583.51	34.3	4 856 314	
10	150 972.11	30.9	4 665 048	
11	160 604.71	28.1	4 512 992	
12	170 491.55	25.75	4 390 157	
13	180 630.51	23.77	4 293 587	
14	191 021.95	22.07	4 215 853	
15	201 666.68	20.6	4 154 334	
16	212 565.26	19.31	4 104 635	
17	223 718.11	18.17	4 064 958	
18	235 125.82	17.17	4 037 110	
19	246 788.80	16.27	4 015 254	
20	258 707.53	15.45	3 997 031	
21	270 882.41	14.71	3 984 680	
22	283 313.87	14.05	3 980 560	
23	296 002.25	13.4348	3 976 731	23.2 ft., economical lift.
24	308 947.99	12.875	3 977 705	$3 976 665, $N = 13.319$.
25	322 151.53	12.36	3 981 793	
26	335 613.05	11.88	3 987 084	
27	349 333.21	11.44	3 996 372	
28	363 311.90	11.04	4 010 963	
29	377 549.94	10.65	4 020 907	
30	392 047.44	10.30	4 038 089	

The present project for the improvement of the Coosa River contemplates the building of twenty-seven locks and dams, from Lock No. 5 to Lock No. 31, inclusive. Lock and lock-house No. 31 have been completed, but the dam, gates, valves, etc., are yet to be built.

Table No. 3 gives the estimated cost of the improvement under the present project; the cost by Equations 1 and 2 for the lifts proposed in the present project, and the minimum costs by Equations 1 and 2, using the economical lifts. It will be noticed that the locks and dams provided for in the approved project, from Nos. 5 to 30 inclusive, have a combined lift of 296 ft., leaving 13 ft. fall in parts of the river where the slope is gentle. It is in these parts that $407 201 would be expended for channel work. In the estimates by Equations 1 and 2 it is proposed to back the water from one lock to another, and locate all locks so that channel work would be eliminated. The difference in cost of the locks of the present project and the costs given by Equations 1 and 2 for the same lifts is due to the substitution of concrete for cut-stone masonry in the latter, thereby reducing greatly their cost. The lock masonry and lock-house for No. 31, being finished, are omitted from the estimates of costs in Table No. 3.

TABLE No. 3.

Number of locks.	Lift, in feet.	Cost (estimated) of present project.	Cost (estimated) by Equation 1.	Cost (estimated) by Equation 2.
4	8	$654 952	$474 975	$529 789
10	10	1 756 670	1 362 473	1 509 721
7	12	1 304 590	1 083 263	1 193 441
1	13	191 734	164 380	180 631
3	14	596 502	522 782	573 066
1	15	204 673	184 393	201 667
Total cost of present project.		$4 709 121		
Dams, abutments, houses, etc.		757 257		
Dams, guide piers, valves, gates, machinery, inspection, Lock No. 31.		11 302*	56 476*	63 270*
Total costs		$5 477 680	$3 848 742	$4 251 585
Minimum costs by Equations 1 and 2, with economical lifts.			3 685 751	3 976 665

* Gates, valves and maneuvering machinery of Lock No. 31.

The minimum costs given by Equations 1 and 2 must be increased by the cost of the dam, guide piers, etc., at Lock No. 31, $56 476 and $63 270, respectively. These minimum costs will then be:

For 4-ft. navigation $3 742 227;
For 6-ft. navigation..... 4 039 935.

The substitution of the economical lifts, 21.5 ft. and 23.2 ft. for 4-ft. and 6-ft. navigation, respectively, and the substitution of concrete for cut-stone masonry, would result in a saving:

For 4-ft. navigation..... $1 735 453;
For 6-ft. navigation..... 1 437 745.

But the present project includes $407 201 for channel work, which is eliminated from the proposed economical project; therefore, the total saving would be:

For 4-ft. navigation..... $2 142 654;
For 6-ft. navigation..... 1 844 946.

Comparing the costs given by Equations 1 and 2, using the lifts of the present project, with the costs given by those equations using the economical lifts, we find that there is a saving from the use of the economical lifts:

For 4-ft. navigation..... $106 515;
For 6-ft. navigation..... 211 650.

Assuming that a lockage requires 20 minutes, there would result a saving in time over the time required for lockages under the present project:

For 4-ft. navigation (26 — 15) 20 = 3 hours 40 minutes;
For 6-ft. navigation (26 — 14) 20 = 4 hours.

The average cost of operating Locks Nos. 1, 2 and 3 on the Coosa River, for ten years past, has been for each lock:

For lock-master's wages	$600
For maintenance	1 000
Total	$1 600

The saving on this item would be:

For 4-ft. navigation (26 — 15) 1 600 = $17 600;
For 6-ft. navigation (26 — 14) 1 600 = 19 200.

Capitalizing these sums at 3%, there would result from this reduction of locks the equivalent of a permanent investment:

For 4-ft. navigation	$586 667.
For 6-ft. navigation	640 000.

The Government, therefore, could spend for overflowed lands the sums saved by the adoption of the economical lift, even though the saving to the public in reduced freight rates, due to decreased lockages, were not considered. These sums are as follows:

For 4-ft. navigation, 106 515 + 407 201 + 586 667 = $1 100 383.
For 6-ft. navigation, 211 650 + 407 201 + 640 000 = 1 258 851.

The uneconomical character of the present project is so apparent, from what has gone before, that in the further discussion of the subject it will not be considered. It should be stated, however, that the present project is designed to have 6 ft. of water over the miter-sills of the locks and 4 ft. in the river channel.

Water Powers.—It has not been the policy of the Government, heretofore, to utilize for commercial purposes the power developed at dams built for purposes of navigation; but the increasing use of electrical transmission of power, and the facility with which such transmission can be operated over long distances to places where the power can be used economically, will probably necessitate an early change in this policy. In view of these changed conditions, it will be well to

consider here the effect which a judicious use of the power developed at the dams on this river would have upon the improvement from an economic point of view.

The low-water discharge of the Coosa River has been estimated variously at from 1 500 to 5 000 cu. ft. per second. Assuming the discharge at 2 000 cu. ft. per second, there could be developed at each dam:

With dams for 4-ft. navigation (21.5 ft.).... 4 887 H.-P.
With dams for 6-ft. navigation (23.2 ft.).... 5 273 H.-P.

Allowing 50% for losses and the maintenance of navigation, there would remain for commercial purposes:

With dams for 4-ft. navigation..... 2 443 H.-P.
With dams for 6-ft. navigation..... 2 636 H.-P.

Assuming that the fall at the dams will disappear when the river below each dam rises to twice its height, which is approximately true, then, to overcome all fall at the dams, it would require:

With dams for 4-ft. navigation, a rise of 43 ft.
With dams for 6-ft. navigation, a rise of 46.4 ft.

Such rises on that part of the Coosa River under consideration are unknown.

The average yearly maximum rise at Lock No. 4 is 20 ft. Such a rise would leave a head as follows:

On dams for 4-ft. navigation, 11.5 ft.
On dams for 6-ft. navigation, 13.2 ft.

By providing additional water-wheels, the low-water power at each dam could be maintained.

The rentals of water-powers in the United States range from $5 to $45 per horse-power per year. Neglecting the fractional dams, and assuming that the Government leased or rented the power at all the others for the reasonable sum of $5 per horse-power per year, the income from this source would amount to:

From dams for 4-ft. navigation..... $171 010;
From dams for 6-ft. navigation..... 171 340.

Capitalized at 3%, these sums would pay interest:

From rental of power at dams for 4-ft. navigation, on $5 700 333;
From rental of power at dams for 6-ft. navigation, on $5 711 333.

In other words, the Government could, from this source, pay interest on the improvement; pay operating and maintenance expenses; and have remaining a sum sufficient to pay interest:

With 4-ft. navigation, on 5 700 333:

$$\left(3\,742\,227 + \frac{24\,000}{0.03}\right) = \$1\,158\,106;$$

With 6-ft. navigation, on 5 711 333:

$$\left(4\,039\,935 + \frac{22\,400}{0.03}\right) = \$924\,731.$$

These sums could be used in the erection of power plants at the dams or for other purposes.

It is not probable that the Government could rent the power at all the dams; but it is reasonable to assume that enough could be rented to pay operating and maintenance expenses and interest on the cost of the improvement.

The Alabama River.—The distance from Wetumpka to the mouth of the Coosa is about 14 miles; but as this part of the river is of the same character as the Alabama, for the purposes of this paper, it will be treated as part of that river.

The distance from Wetumpka to the mouth of the Alabama is 332.5 miles; the fall is 105 ft.

The banks of the Alabama are low, and the bottom lands on either side extend back 5 to 10 miles from the river. Like the Mississippi, the Alabama has banks that are caving constantly, and a bottom ever on the move; and unless movable dams were used, the pools would soon fill, leaving the river in worse condition than now, for constant dredging between locks would be necessary to maintain a channel. If dredging will have to be resorted to finally, then the construction of locks and dams, leaving out of consideration the danger to adjoining lowlands, would be more than a useless expense, and, therefore, the problem of improving this river resolves itself into a question of maintaining a low-water channel of the required depth by means of dredging.

The question of works of contraction is not considered, for experience on this and other rivers of the same character has been that such works merely move the obstructions, which they are intended to overcome, further down stream, and, that, to make such works effective, they would have to be built in such manner and places as to

give the river, as a whole, a uniform slope and cross-section. The cost and maintenance of such a system would be prohibitive.

Unfortunately, no data exist upon which an accurate estimate of the improvement of the Alabama River can be based; but the writer believes, from his personal knowledge of this stream, that the estimates for dredging that follow are sufficient to maintain the channels proposed.

The following is an estimate of the annual cost of operation of one dredging plant:

One dipper dredge of 1½ cu. yds. dipper capacity.	$15 000
Three dump scows	9 000
One steam tender	15 000
Total	$39 000

Assuming renewals every 15 years:

Cost per year for plant	$2 600
Repairs	300
Crew of dredge, 6 months	1 710
Subsistence, 6 months	600
Fuel for dredge, 6 months	500
Oil, waste, etc., 6 months	130
Tender crew, 6 months	1 830
Fuel for tender, 6 months	500
Subsistence, 6 months	600
Repairs, 6 months	200
Oil, waste, etc., 6 months	130
Two watchmen, 6 months	360
Contingencies, 10%	960
Total	$10 420

Assuming that six such dredging plants would maintain a 4-ft. channel and eight plants a 6-ft. channel, the cost per year would be:

For 4-ft. navigation $62 520;
For 6-ft. navigation ..... 83 360.

Capitalized at 3%, these sums would be interest charges on permanent investments:

For 4-ft. navigation $2 084 000;
For 6 ft. navigation ..... 2 778 667.

The total economical cost for the improvement of this system of rivers would therefore be:

For 4-ft. navigation:

Improving the Coosa River	$3 742 227
Improving the Alabama River, annual cost capitalized at 3%	2 084 000
Operation and maintenance of locks, Coosa River, capitalized at 3%	800 000
Total	$6 626 227
Deduct rental of power, capitalized at 3%	5 700 333
Cost to the United States	$925 894

For 6-ft. navigation:

Improving the Coosa River	$4 039 935
Improving the Alabama River, annual cost capitalized at 3%	2 778 667
Operation and maintenance of locks, Coosa River, capitalized at 3%	746 667
Total	$7 565 269
Deduct rental of power, capitalized at 3%	5 711 333
Cost to the United States	$1 853 936

Almost exactly twice the cost of the improvement for 4-ft. navigation.

But there is another factor entering into the problem: The freight rate. As coal will probably be the principal freight carried on this system of rivers, it is taken as the basis of comparison. The locks, as designed, will take at one lockage three barges and one towboat. This fleet is the basis of the following estimate:

		For 4-ft. channel.	For 6-ft. channel.
Cost of steamboat	per year	$667.67	$800.00
Cost of barges	"	500.00	600.00
Repairs	"	300.00	325.00
Interest on first cost at 4%	"	700.00	840.00
Insurance at $\frac{5}{8}$ of 1%	"	75.00	93.75
Taxes	"	187.50	225.00
Two Masters	"	1 680.00	1 680.00
Two Engineers	"	1 200.00	1 200.00
Two Firemen	"	960.00	960.00
Six Men	"	2 160.00	2 160.00
Subsistence	"	1 200.00	1 200.00
Fuel	"	1 000.00	1 200.00
Supplies	"	200.00	200.00
		$10 830.17	$11 483.75

Cost per trip, thirty trips per year	$361.00	$382.79
Capacity of fleet	848 tons	1396 tons
Cost per ton of freight	$0.426	$0.274

Now, the value of any improvement is inversely as the first cost, the capitalized cost of operation and maintenance, the cost per ton freight rate; and directly as the capitalized investment resulting from the rental of power developed at the dams. Applying this rule to the present discussion, we have:

$$\text{For the value of 4-ft. navigation } \frac{5\,700\,333}{3\,742\,227 + 2\,084\,000 \times 800\,000 \times 0.426}$$

$$\text{For the value of 6-ft. navigation } \frac{5\,711\,333}{4\,039\,935 + 2\,778\,667 \times 746\,667 \times 0.274}$$

Dividing the second equation by the first, we find that the value of 4-ft. navigation is to the value of 6-ft. navigation as 1 to 1.4621.

The tendency, in the United States, is to increase the navigable depth in rivers under improvement. Upon the system of rivers under discussion, at least, this is good practice, both from the point of view of the carrier and as an economic proposition. There is, unquestionably, an economic depth, just as there is an economic lift, but this paper cannot go further into a discussion of that phase of the problem.

In the final location of the locks on the Coosa River, it will be impossible, of course, to adhere to the economic lift indicated, but it will be possible to approach it, and the nearer the approach the more economical the improvement.

The writer has had access to excellent maps and profiles of the part of the Coosa River under consideration. The maps, however, do not show the topography of the adjacent country, and, therefore, it has been impossible to estimate the cost for levees and overflowed lands; but, as before stated in this paper, the banks are high, and in many places precipitous, and these costs would be comparatively small. This part of the Coosa is an ideal stream for locks and dams of high lift.

The writer knows of no good map of the Alabama River, and, as far as his knowledge goes, there is no profile in existence. The estimates for that river are made from his personal knowledge of the stream, and are believed to be safe.

The writer's investigations have led him to the following general conclusions concerning the improvement of rivers in the United States:

All streams, east of the Mississippi at least, and generally those west of that river, may be classified under two heads, which, for want of better names, will be called torrential and alluvial.

Torrential streams are those pouring down from the mountains and plateaus, and emptying generally into alluvial streams. They can only be opened to navigation by means of locks and dams.

Alluvial streams are those flowing through the coastal plain, and are always continuations of torrential streams. Except when the flow is insufficient to maintain the required navigable depth, alluvial streams should never be improved by means of locks and dams, for, with their caving banks and moving bottoms, the pools would soon fill, and constant dredging would be required to keep them open to navigation. Movable dams would remove this objection, but, with the present navigation on our rivers, their cost is prohibitive.

The use of isolated works of contraction on alluvial streams is a mere expedient, for their only effect is to move the obstruction further down stream. Of course, other contraction works could be built, until the obstruction was removed to the mouth of the river. Such extensive works of regulation would result in giving the stream a uniform slope and cross-section, and are an excellent method of improvement, except as to the cost, which would be enormous.

Finally, there is left the method of maintaining a temporary channel, during periods of low water, by dredging. This is the cheapest, and, with the present traffic on our rivers, is the one that should be used.

Our larger problems of river improvement embrace the study of the regulation of both torrential and alluvial streams in one and the same project. Every such system should be treated as a whole. It is as bad practice to have one part of a system improved for one depth of navigation and another for a different depth as it would be to have different gauges in the same system of railroads.

The time has come when the power developed by dams built for purposes of navigation should be used in the industrial development of the country. This being true, why should not the public at large, as represented by the Government, reap some of the benefits?

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PAPERS AND DISCUSSIONS.

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A HIGH-VOLTAGE POWER TRANSMISSION.

Discussion.*

By Messrs. F. O. Blackwell, P. H. Thomas, W. B. Potter, J. R. McKee and M. H. Gerry, Jr.

F. O. Blackwell, Esq.—There are some features of electric power transmission which may be of interest. The first is that it is practically independent of distance. If a potential is used which is proportional to the distance, any distance can be reached. It does not matter much whether the power is carried across the room, or whether it is carried 100 miles—the same quantity of copper per horse-power is required for the same efficiency. Mr. Blackwell.

Having this independence of distance, the generation of power can be concentrated from several different places in one power-plant, for instance, from Helena and Butte, as has been done in this particular instance. The reverse can also be done; that is, the power can be brought from many different points and delivered to one place to be used.

Butte is also a good example of this. They have, at a water-fall near Butte, three electric power transmission plants, in addition to a 3 000 H.-P. steam-driven electric plant in the City of Butte. They bring 5 000 H.-P. 60 miles from the Missouri River, 2 000 H.-P. 67 miles from the Madison River, and 2 000 H.-P. 20 miles from the Big

* This discussion (of the paper by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., printed in *Proceedings* for January, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to May 23d, 1903, will be published subsequently.

Mr. Blackwell. Hole River, into the city. Three of the plants are working together, as if the generators were all in the same building, notwithstanding their great distance apart.

In some parts of the country they have as many as seven or eight steam- and water-power electric stations, perhaps 50 or 100 miles apart, all feeding into the same distribution system and working in unison like one plant. Power, to-day, is being delivered commercially to San Francisco and the neighboring cities from two water-powers 150 miles away. Temporarily, power has been transmitted 220 miles, by connecting the two transmission systems referred to.

Another characteristic of electric power transmission which is important is the high efficiency obtained regularly from electrical apparatus. If 80 or 90% efficiency is obtained from a steam-engine or a water-wheel it is a remarkably good result, but, in a large electric generator, as high as 97% can be obtained, and transformers changing from one potential to another have given more than 98% efficiency.

The efficiency of the power transmission is entirely a matter of how much copper is put in the transmission circuit, but it is seldom that more than 10% is lost in conductors, even with the long-distance transmissions already referred to.

Mr. Gerry does not mention the efficiencies of his apparatus and transmission, but Mr. Thomas is very familiar with the Missouri River plant, and has made many tests upon it. It would be interesting to hear from him as to the results of his experiments, and particularly as to the efficiency of the transmission to Butte.

Mr. Thomas. PERCY H. THOMAS, Esq.—The speaker has spent some time at the plant of the Missouri River Power Company, but, as he has not been connected with the company officially, he is not able to speak authoritatively of what has been done there. A few interesting points, however, might well be mentioned.

The speaker has not seen the figures giving the efficiency of the plant as a whole, but, for purposes of comparison, it can be imagined that power is transmitted from Canyon Ferry to Butte with as little loss as with a fair belt transmission of 15 or 20 ft.

Mr. Gerry has stated that, as far as he knows, this line has the highest voltage in commercial operation, and, probably, he is correct, though another plant which will use the same voltage is being installed and is about to be run.

This Canyon Ferry plant is remarkable in a number of ways: It is remarkable as to the country through which the transmission line passes; it not only crosses three mountain ranges, but one of these is the Continental divide—however, it is not the only line which crosses that divide. It is subject to very great changes of climate and temperature, and passes through extreme ranges of altitude. Lightning, in certain parts of the country traversed, is very severe, and Mr.

Mr. Thomas.

Gerry says he has noticed, near Helena, that the lightning—sometimes very severe discharges—generally comes out of a clear sky. The rain follows, but by that time the danger is over. At this plant there is great difficulty in getting intelligent electrical men of the various grades, as they are not very plentiful in that part of the country.

In spite of all these difficulties, and many others, Mr. Gerry has succeeded very well. On March 7th, 1903, the plant will have completed a year's commercial operation. The continuity of service seems to have been very satisfactory, though the load handled, *viz.*, large motors, is of a type which is generally considered very difficult. The work in Butte has been the running of compressors, pumps, concentrators, etc. The street railroad is run by another plant.

The following is a feature which, perhaps, is somewhat interesting to civil as well as electrical engineers. Consider one of these 70-mile transmission lines charged up to the pressure of 50 000 volts; the energy stored therein, or that required to bring it to this condition, is about equal to 1 B. T. U. It seems remarkable that such a long line can be charged with so small an amount of energy and to such a high potential. Not only is this true, but it is also found, in practical service on such circuits, that the charging and discharging of this small amount of energy in some unexpected direction, as by accidental short circuits, cause some of the greater difficulties of operation.

During the summer of 1902 Mr. Gerry and the speaker made a number of tests on this plant, trying to determine some of the resultant strains on the apparatus caused by a discharge of this British thermal unit in an unexpected direction, for instance, such an action as might be brought about by a tree falling across the wire.

Mr. Gerry almost has the record for continuous service on a transmission line at his Helena 12 000-volt plant. At no time during 24 or 26 months was the potential off the bus-bars at the substation in East Helena. That is a record which is difficult to equal in almost any kind of power work.

The question as to the possible effect of such a transmission line as this on long-distance telephone transmission is interesting. The telephone and high-tension lines are parallel for a number of miles. The power lines are 78 ins. apart and the telephone line, which is placed upon one of the two pole lines, is not much more than that distance from the lowest wires, but is pretty well up on the pole. Before Mr. Gerry started to operate his plant the man in charge of the long-distance telephone system feared that the high voltage would interfere with his work, and made a particular request that he be notified before the plant was started. By some oversight the plant was started without notifying him, and had been running for two weeks before he discovered it. Thus it can be considered that there is no very great danger—at least during normal operation—from the parallelism of such lines.

Mr. Thomas. Mr. Gerry has introduced one important feature in the construction of his pole line which may or may not be new. In running his wires over the country, he did not follow the slopes of the land in detail, but put in short and tall poles in such a way that the wires run on smooth grades and thus strains on the insulators and pins are avoided. In going over a summit he rounded off the top so that the highest pole carries no excessive weight.

Mr. Potter. W. B. POTTER, Esq.—How best to secure a maximum result with a minimum expenditure is an ever-present problem with the engineer. For short distances the economy of electrical transmission is limited by the mechanical strength of the transmission lines necessary for reliability; and a high economy of transmission can usually be secured at relatively low voltages. Over long distances the size of the wire may still be that necessary for mechanical strength, provided the voltage is increased correspondingly.

The installation described by Mr. Gerry is of particular interest as showing what can be accomplished at 50 000 volts, and the details and precautions taken to insure against accidental grounding of the transmission circuit. The speaker has been much interested and pleased to hear, through Mr. Thomas, of the reliability and efficiency of the service given. It is creditable to Mr. Gerry and the designing engineers of the power-station and substation apparatus that these results have been secured at what but a few years ago would have been considered an impracticable voltage.

Mr. Thomas has informed the speaker that, as far as he knows, the 78 ins. between transmission lines has proved ample to protect them against an arc being maintained in the event of its being established accidentally.

At one time it was considered that about 1 in. per thousand volts would be sufficient, but assuming, for mechanical reasons, a minimum distance of 18 ins., recent practice indicates that about $1\frac{1}{2}$ ins. per thousand volts should be allowed, principally on account of the possibility of an arc being maintained between the wires in case it should be established accidentally. The speaker knows of several instances where the ubiquitous boy has derived much pleasure, and a display of fireworks, by throwing a wire across the lines. The arc thus established would be maintained and travel a considerable distance in the direction of the wind before being extinguished. The speaker believes it is a matter of record that, in one of the western systems, the transmission line was short-circuited, and the power-station shut down, on account of two large birds alighting on adjacent wires and endeavoring to communicate. They succeeded in establishing the connection, to their own undoing. It is perhaps a point worthy of consideration to take due account of the dimensions of the birds in the territory through which the lines may pass, and this suggestion is not necessarily confined to our western States.

Mr. Potter.

Mr. Gerry mentions that the high-potential wiring within the stations is rubber covered, although the insulators on which it is mounted are evidently the main reliance for insulation. As the rubber covering on the wire can hardly be considered a protection, would it not be safer to run the wires through brick or cement compartments, in which event the wires could be left bare and thus lessen the quantity of inflammable material?

The term "load factor" has been mentioned several times, and it has been the speaker's experience that the exact meaning of this term is sometimes misunderstood. Many power-stations have reserve apparatus, which is not operated during the 24 hours, and he has found that there is a difference of understanding as to whether load factor is the percentage of average load to the machines in operation for the actual time they may have been running, or to the installed apparatus. The former is the usual and proper definition, and the speaker would suggest the term "station factor" to represent the average output, in percentage, of the total capacity of the apparatus installed.

The transmission of electrical energy is the solution and problem of electric power for the movement of traffic. The location of water-powers and the economy of steam-power necessitates generating power in large quantity and distributing it to the points of application. Instead of direct-current power-stations, 10 miles apart, and operating at a low load factor, alternating power-stations are now being built which transmit at high potential to substations 10 miles apart, more or less. Depending upon the character of service, the range covered by a given potential will vary from 1 to 2 miles per thousand volts; that is, if the service were subdivided and the cars of medium size, a 50 000-volt transmission, with the power-station located in the middle, would operate economically a railway 200 miles long, the limitation, of course, being the power required by the most distant substations.

The speaker believes that an unprecedented development in the railway field may be looked forward to during the next five years; and the problem of "high-voltage power transmission" will be one of the most interesting with which the engineer will have to deal.

Mr. McKee.

J. R. McKee, Esq.—The speaker has the good fortune to belong to the same department in an electric company as that with which Mr. Blackwell is identified, and for all engineering questions has been in the habit of looking up to him.

The question: Can you transmit power electrically over very long distances? has been asked very frequently. It is only a very few years ago that doubt was expressed as to whether power could be transmitted economically over what are to-day such comparatively short distances as 10 or 20 miles.

The limitation to-day, in the handling of electricity for the transmis-

Mr. McKee. sion of power, is more of a mechanical than an electrical problem, and is confined largely to securing an insulator capable of withstanding the very high voltage necessary for economical, or, in other words, commercial, transmission over great distances, such as anywhere from 100 to 500 miles.

One particularly interesting feature in this plant is the use of a glass insulator for a 62-mile transmission over a wire carrying current at 40 000 volts. The speaker thinks there are but two plants in the United States where dependence is placed upon glass insulators for high voltage. One is at Provo, Utah, where, at times, a line has been coupled up for 130 miles, and where a voltage as high as 50 000 was used experimentally, although the normal operative voltage is about 40 000. The second plant transmits at 40 000 volts, 62 miles, from the Madison River to Butte, Mont.

Originally, the question of carrying current over long distances was largely dependent on the possibility of securing a transformer which would withstand a high voltage. Only a few years ago—say five or six, without stating it at all definitely—the electric companies did not care to undertake anything higher than 20 000 volts, and then their guaranty was that if they did not at first succeed, they would not stand for damages, but would try again. To-day, transformers are constructed and have been put into operation for as high as 100 000 volts, and, no doubt, as the art progresses, even higher potentials will be handled safely.

The attention of those who are interested in hydraulic work should be directed to the excessive cost which, unfortunately, is shown by so many of the first transmission plants, and which, in nearly every case, has been due to a misunderstanding of the hydraulic features.

The installation of water-wheels connected directly to the generators seemed to call for different methods or rules of calculation, as against those used in ordinary mill plants, where the load is not as variable and where the necessity for close regulation is not as great. The result has been that many of the earlier hydraulic plants, installed for the generation of electricity for transmission, have had to be overhauled, and, naturally, at very great expense, both as to actual expenditure and loss of time.

In one prominent plant the power-house is one of the most substantial granite structures to be found anywhere, and the hydraulic part of the entire plant cost nearly $500 000, but recently it has had to be altered, at a cost of not less than $100 000, because the water could not reach the wheels freely enough to take care of the varying load on the generators with sufficient promptness to give the necessary regulation.

In still another plant, costing more than $300 000 for the power-house, more than $75 000 has been spent in trying to get the water to

Mr. McKee.

the wheels more freely, the trouble being that the wheel-chamber was too small and the draft tubes not quite liberal enough in capacity to provide and carry away the water, respectively, when there was a sudden and large variation in the load, and to do it promptly enough to insure the regulation which is necessary in an electric plant.

Comparatively few people realize the extent to which water-powers are being depended upon to solve the question of cheap power, and also the rapid increase in the number of plants of this character. A very interesting installation is that at Salt Lake City, where, starting with a small transmission plant about 15 miles from Salt Lake City, they afterward put in a second plant, near Ogden, carrying the water through a 6-mile pipe line to the power-house and transmitting it 36 miles to Salt Lake City at 30 000 volts, an accomplishment which at that time (about six years ago) was considered very little short of wonderful. Both transmission plants are operated in synchronism with the steam station located at Salt Lake City.

At Butte, Montana, a plant installed on the Madison River, 62 miles distant, is transmitting over a line of aluminum wires at 40 000 volts, and delivering current to the bus-bars of the Butte Lighting Company in synchronism with current brought over another line of 21 miles from a water-power on the Big Hole River, and also with current generated in a steam plant in Butte.

The street railway and lighting system of the Cities of Seattle and Tacoma are operated largely by current brought 42 miles, over an aluminum wire, from a water-power on the Snoqualmie River. An additional water-power plant, located about 30 miles distant, is now being installed, in which 15 000 H.-P. will be generated for transmission to the same market. A third plant, of not less than 20 000 H.-P., to be installed on a third river, some 35 miles from Tacoma, is under consideration.

When these installations are complete, there should be no occasion for the use of any fuel whatsoever for the generation of power in either of these cities or in the locality, there being sufficient water-power to supply all the wants, fuel then being used only where it is required for heat, and the speaker is not absolutely sure but that the cost of electric current, due to the low cost of operating by water-power, may come down to a price so low that even heat can be supplied economically.

Los Angeles, California, one of the centers for oil—in other words, where fuel is cheap—has become one of the greatest transmission centers in the country. There are at present two water-power transmission plants delivering current to this market. One of these is located 85 miles distant, and the other about 20 miles. A third one, located approximately 110 miles distant, is being installed for 15 000 H.-P., and a fourth once, located about 125 miles distant, where they expect

Mr. McKee. to install 20 000 H.-P., is to be undertaken within the next few months. When all these plants are in operation, notwithstanding the low price of fuel at Los Angeles, it is probable that there will be very little steam power used in that city.

The different cities just referred to are only a few of the many in the United States which are being supplied rapidly with electric power generated from water-powers; and, inasmuch as current to-day can be carried distances of 100 to 200 miles economically, it is easy to comprehend how rapidly this method of supplying power will grow. In the spirit of prophecy, the speaker thinks it reasonable to anticipate that it will be only a few years, comparatively, before practically all the power used in manufacturing in New York State, north of a line drawn west from Albany, will be supplied by water power. The possibilities from water stored properly in the Adirondacks are such that, when fully developed, several hundred thousand horse-power of electricity can be generated therefrom for transmission purposes, and with the flood waters held back and stored so as to be released through the usual low-water periods, these water-powers can be made sufficiently uniform to justify their being depended upon for manufacturing purposes; so the rule will be that probably fuel in that section of the State will be used only where heating is a consideration.

With Niagara on the West, the St. Lawrence River on the North and the Adirondacks in the interior, the possibilities for power development are almost unlimited, and the assurance of cheap power equally promising. In the locations where the great developments just mentioned have been made, the natural supposition, particularly at Seattle, would be that there would be a great decrease in the consumption of fuel. This, however, does not seem to have been the case, because, as manufacturing has grown, the increased demand for fuel for use on locomotives and steamships—in other words, for transportation—seems to have more than offset any decrease in its use for manufacturing purposes.

Mr. Gerry. M. H. GERRY, Jr., M. Am. Soc. C. E. (by letter).—Of the greater uses of electricity to-day, perhaps the most important is that of an agency for the transmission of power. It is the connecting link by means of which mechanical energy, generated at distant points, is transferred and again converted into mechanical power under conditions favorable to economical application for commercial purposes.

Mr. Blackwell reminds us of the ease and reliability with which distant generating plants may be worked together, and of the high efficiency attained, as compared with all other methods of transmitting power. These are interesting facts, and are evidence of the desirability and flexibility of the agency under discussion.

Mr. Thomas speaks of the effective lightning protection and successful telephone service maintained on the Butte transmission. His

remarks indicate that difficulties recently considered serious have been overcome, and that there is little reason to fear interruptions of the service from such causes on long transmission lines. Mr. Gerry.

Mr. Potter, in his interesting discussion, states that 1½ ins. per 1 000 volts should be allowed between wires on account of the possibility of an arc being maintained if once accidentally established between conductors. The wires on the Butte transmission are placed 78 ins. apart, but for reasons other than those mentioned by Mr. Potter. It is true that an arc will not be maintained at this distance in the open air, under 50 000 volts, nor will it be maintained at a somewhat lesser distance. The wires are so spaced as to control the brush discharges, the electro-static losses, and also to establish a certain line capacity. The rubber insulation of the wires in the station, to which attention is directed by Mr. Potter, is there for the purpose of reducing the brush discharge where the connections are near together, at the terminals of the transformers, and other apparatus. The thickness of the rubber, as stated, is ample to withstand the full electrical pressure. Brick and cement compartments, unless of very great size, are undesirable for high potentials, and even then do not represent the best form of construction.

In closing his remarks, Mr. Potter made an interesting allusion regarding the relation of high-tension electrical transmission to the problem of applying electrical power to the movements of traffic on the present steam railways. An electric railway, primarily, is an electrical power transmission. Its possibilities and scope have been limited in the past by reason of the use of direct current only, thus restricting the field of operation to comparatively short distances. A combination of alternating current transmission, with direct current distribution and application has met with some success in recent years in connection with electric railroading, but this must be regarded as but a temporary expedient, and not as a solution of the problem. There are no inherent reasons why alternating current may not be applied directly to railway service, and thus render possible the general use of electrical power for all classes of railways. There are, in truth, difficulties to be overcome, but they are in reality fewer than confronted the electrical engineers of even ten years ago, in applying direct current to city railway service.

Mr. McKee calls attention to the fact that transformers can now be obtained for electrical potentials up to 100 000 volts. This is certainly a high pressure, but there are no serious obstacles in the way of the use of this voltage on transmission lines where the conditions are such as to warrant the installation. The limit of electrical tension for the transmission of energy has not, as yet, been reached.

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PAPERS AND DISCUSSIONS.

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SAND-BLAST CLEANING OF STRUCTURAL STEEL.

Discussion.*

By Messrs. Charles E. Fowler, William A. Polk, J. P. Snow, Theodore Belzner, Theodore Paschke, A. H. Sabin, Henry B. Seaman, E. A. H. Tays and George W. Lilly.

Mr. Fowler. Charles Evan Fowler, M. Am. Soc. C. E. (by letter).—This paper is certainly one of the most important that has ever been presented before the Society. The failure to clean the metal of steel structures properly before they are painted is the principal cause of their deterioration, and, practically, is the only cause which exists as a prejudice against them. While the bridge shops have, in most instances, endeavored to clean the steel properly before paint is applied, it has never been done satisfactorily, in the majority of cases, owing to the character of the plant used, and owing to the character of the help which it is necessary to employ on work of this kind. The laborers ordinarily employed as painters about bridge works are not possessed of a very high order of intelligence, and soon fall into the rut of glossing over and slighting their work. When they are discharged, and new ones put in their places, there is always a length of time for breaking them in, during which the work is not done properly, so that the writer believes that, necessarily, it must come to some such method as sand-blast cleaning at the bridge shops before painting is done, or else follow the lead of some European railroads, where the bridges are not painted until some time after erection.

* This discussion (of the paper by George W. Lilly, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to May 23d, 1903, will be published subsequently.

Mr. Fowler.

The specifications of the Sheffield and Lincolnshire Railway Company for 1889 require that no portion of a structure shall be painted before erection, except such parts as are not accessible for painting afterward. Some time after the structure is erected, and the scale has all disappeared by rusting off, the metal is cleaned thoroughly and painted. Should this be done by the sand-blast process, and paint at once applied, there would be some surety of a proper protection from future rusting.

Many engineers seem to object to allowing rust to appear upon the steel at all, preferring to have the metal kept under cover from the time it is rolled until it is fabricated and painted, but anyone who has had experience with raw steel plates and shapes stored in a yard, will know that the mill scale, which very often is not removed otherwise, is rusted off, and the solid metal, although coated with rust, can be gotten at so as to be cleaned thoroughly and painted; whereas, if the metal is kept under cover, much of this scale remains on and is painted over, and in a few years flakes away from the metal, or rusting between the scale and the body of the metal goes on unseen.

In the writer's opinion, particular parts of bridges should be galvanized, in a great many cases, or protected by Barffing, so as to give them a protection once for all; but, in lieu of this, the thorough cleaning of existing structures by a method similar to that used by Mr. Lilly should be followed, and the coating applied directly afterward to protect the steel thoroughly. In such cases it will be possible soon to arrive at some definite idea as to which paint is really the best to use on bridges and steel structures.

While not directly a feature of Mr. Lilly's paper, it certainly is one which comes up in studying it, as to what kind of paint is really the best. The writer is not prepared to change his opinion, formed during many years as Chief Engineer of one of the large eastern bridge companies, that red-lead paint is the best that can be applied, regardless of the numerous paints which are advertised so loudly as the best for protecting steelwork. Red lead, used according to the Baltimore and Ohio specifications of 1896, by the addition of 10 oz. of lampblack to every 12 lbs. of red lead, can be handled as easily as any other paint. Next to this, for first-class work, are the various carbon paints put on the market by the standard paint companies.

While the writer has no data of his own, as to the cost of sand-blast cleaning, it appears from the paper that the cost can be reduced to a reasonable figure, and one which would warrant the use of the method whenever there is a large amount of cleaning to be done.

If this paper shall have served no other purpose than to have called attention in a forcible way to the need of thorough cleaning of steelwork before painting, it will have proved itself to be one of the most valuable papers ever presented for the consideration of engineers having to do with steel structures.

Mr. Polk. WILLIAM ANDERSON POLK, Assoc. Am. Soc. C. E. (by letter).—The writer has read this paper with much interest, especially that part relative to cleaning the One Hundred and Fifty-fifth Street Viaduct, in New York City. During this operation the writer had the pleasure of devoting about one month's time to observation of the workings of the sand-blast, and found that it was the only power capable of removing the accumulated rust scale with despatch and economy. Moreover, it was the only method that was thoroughly efficient in preparing the surface for the tests of paints, that being the object for which the sand-blast was used on the viaduct.

To understand how thoroughly the machine did its work, it may be stated that on days in which the humidity was great (such days were frequent, the humidity registering often from 90° to 98°), the metal was no sooner cleaned than the gray color was changed by oxidation to a rusty brown. It was deemed expedient to apply the paint as soon as possible after a sufficient number of square feet (about 200) had been cleaned. This surface would comprise two buckle-plates, one on each side of the girder, and the section of the girder supporting these buckle-plates. The cleaned surface was protected from sand by a screen of sail cloth while the machine was being operated.

Notwithstanding this protection, a great deal of fine dust settled on the cleaned portion. This dust was readily taken up by the paint, however, and, in the writer's opinion, did no harm. One painter could finish in two hours the portion which had been cleaned by one nozzle-man in eight hours, under favorable conditions, *viz.*, in dry weather and with dry sand. Four nozzle-men could keep one painter busy, but, to accomplish this, the sail-cloth screen had to be moved frequently to places where protection might be necessary. On bridges at other places the writer has noticed that a screen was not needed.

The expense of cleaning the One Hundred and Fifty-fifth Street Viaduct was necessarily much greater than it would be to-day. The cost and the time of cleaning could be reduced very much by the addition of more machines.

For the purpose of preparing metal surfaces for painting, nothing has come under the writer's observation, during a period of ten years, that can approach the efficiency of the sand-blast machine. In order to have the best results from painting, it is expedient, nay, it is necessary, to have the surface absolutely free from rust, mill scale and grease; therefore the sand-blast will more than pay for itself in decreased maintenance and in furthering the lasting qualities of metal coatings.

Mr. Snow. J. P. SNOW, M. Am. Soc. C. E. (by letter).—The Boston and Maine Railroad (with which the writer is connected) has used a sand-blast outfit for four seasons, but from its experience little can be added to the testimony given by the author. The mixers used are of the

Tilghman pattern, as shown by Fig. 1,* with a second hopper, so that sand may be fed continuously while the blast is operating. Mr. Snow.

The air is furnished by a Fairbanks-Morse gasoline compressor, with an 11-in. engine cylinder and a 14½-in. pump having an 18 in. stroke. Two, and sometimes three, open-topped galvanized-iron tanks, of 600 galls. capacity, each containing circulating water for cooling the cylinders, are used; these, and a small galvanized-iron gasoline holder, a boiler-iron air-reservoir, a sand-dryer, and pipes, hose, etc., complete the outfit.

The air pressure with this plant is from 15 to 18 lbs., which is very effective on weather rust not heavily scaled. Where the scale is caused by engine gases or by brine from refrigerator cars it is removed with hammers, chisels, etc., before applying the blast. It is thought that a greater pressure, as advocated by Mr. Lilly, would be more effective where the rust is heavy and the metal pitted. The pressure can be increased by exchanging the pump cylinder for a smaller one.

Usually, this outfit is loaded and unloaded by a car derrick. It is set up near the bridge to be operated upon, the water tanks are filled from the locomotive tender, a detachable shanty is put over the engine, sand is unloaded, the pipes are connected, and work is commenced. It requires only a few hours to set up the plant at a given bridge. It is desirable to have the sand-dryer as near the bridge as possible, but the engine should be 100 ft. away, or further, to get it somewhat out of the dust.

The sand should be clean and hard. For the highest efficiency, its fineness should depend on the kind of rust to be attacked. For simple weather rust, fine sand is the best. If the rust is heavy, the metal pitted and the surface hard to get at, coarse sand should be used. Where the work is over dry land, the sand can be used again several times. It gets finer each time it is used, but, as the impact against the metal breaks the grains of sand, they are sharp, and, until it becomes too fine, its effectiveness is rather greater than at first.

For drying sand a so-called Chicago dryer is used. Its action is similar to that of the dryer shown in Fig. 1, Plate XVII,† except that the dry sand escapes through an annular opening against the fire-box, which prevents, in a measure, the over-heating mentioned in the paper. This method of drying sand is very unscientific, however, inasmuch as the mass of sand in the hopper acts as a blanket to prevent the escape of steam from the lower portion next to the fire-pot, where there is the greatest heat. In fact, it is a good deal like trying to drive moisture out of a steam-tight box. A dryer, arranged so that the sand could fall over a series of inclined baffle-plates in a furnace, where the heated gases from the fire could pass over a thin moving sheet of sand and absorb its moisture, is a desideratum. The waste

* *Proceedings*, Am. Soc. C. E., for February, 1903, p. 133.
† *Proceedings*, Am. Soc. C. E., for February, 1903, p. 147.

Mr. Snow. heat from the engine exhaust is enough to dry the sand in a properly arranged dryer, but there are practical difficulties in using it. The exhaust from an explosion engine should be free and close to the engine, to obviate back pressure; but, to save the running parts, the engine should be at some considerable distance from the sand. Again, it is frequently desirable to dry sand when the engine is not running; therefore, on the whole, it seems best to use an independent dryer.

Some difficulty is experienced from moisture carried by the condensed air. A very little dampness will cause the sand to clog at the lower valve, as mentioned in the paper; but, with drips at the air reservoir, and no sags in the lines of air pipes, the trouble is not great.

In cleaning a long bridge the air has been carried as far as 900 ft. from the reservoir. A 3-in. pipe is used, and there is very little reduction in the pressure from the reservoir to the mixers.

The operation of painting is similar to that described by Mr. Lilly. On overhead bridges, which suffer from the blast action of the locomotive smokestacks, it is not considered a disadvantage to have the sand get into the raw paint. Two coats are applied, and the portion directly over the centers of the tracks receives three coats. If the first is well filled with sand the result is a thick, gritty coat, which has considerable power to withstand the blast of hot sparks from the stacks.

With the engine described, three mixers and nozzles are used. The force required is generally a foreman and six men; three on the nozzles and three drying sand and feeding it to the mixers. The writer has no reliable statistics as to cost. The figures given in the paper are fairly comparable with average results obtained, but many jobs cost more on account of the difficulty of getting at the parts to be cleaned. The question simply resolves itself into a choice between letting the metal waste away at its own rate, or paying the cost of cleaning it with the sand-blast. Where iron has become heavily scaled by locomotive gases, brine from beef cars, or sea water, it is simply impracticable to stop corrosion by any method, known to the writer, other than the sand-blast.

Mr. Belzner. THEODORE BELZNER, Jun. Am. Soc. C. E.—In this paper Mr. Lilly has carefully covered the ground, and has left little to be added except practical experiences in the same line. A number of his recommendations should be carried out, and, if criticism were to be made, it would have to be said that he does not place sufficient emphasis on some of his recommendations.

The speaker will endeavor to relate the experience gained in the sand-blast cleaning of steel on the Rapid Transit Subway, in New York City.

Mr. Belzner.

Owing to the magnitude of the Rapid Transit Subway work, steel had to be ordered largely in advance from the manufacturers, who in this case were the American Bridge Company. Such steel as columns and girders of standard size and design were ordered, so as to facilitate the output at the mills. Large quantities were received, and lay for from eighteen months to two years, piled high in the streets and at the yard at the foot of Forty-second Street, East River. This steel was exposed to the inclemency of the weather for that period. When the sub-contractors were ready to use the steel it was found that the paint had worn off considerably, and a part of the steel was corroded. It was determined to clean and repaint before erection such parts as were to be exposed in the structure, and all abutting and connecting parts which were not to be embedded in concrete. S. L. F. Deyo, M. Am. Soc. C. E., Chief Engineer for the Rapid Transit Subway Construction Company, acting on the recommendation of William Barclay Parsons, M. Am. Soc. C. E., Chief Engineer for the Rapid Transit Commission, then gave the order to the sub-contractors to clean the steel with the sand-blast.

Before taking up the work in detail it should be stated that the various sub-contractors had established air-compressing plants on their various sections, thus having their line covered with compressed-air pipes.

A large quantity of steel was piled at Canal and Elm Streets, and work was commenced there, but was found to be such a nuisance to the tenants of surrounding buildings and to traffic that it was moved down into the partly-finished subway. Here the dirt and sand became a hindrance to the workmen, and the work was moved to Bond and Elm Streets. Here, again, it proved to be such a nuisance to the public and to traffic that the operation of the blast was confined to night hours. Work was then carried on at this point for a long time until the street was cleared for paving. The plant was then moved to Forty-second Street and the East River, where, again, work during the day was found to be objectionable to the neighborhood, and the work is now being done at night.

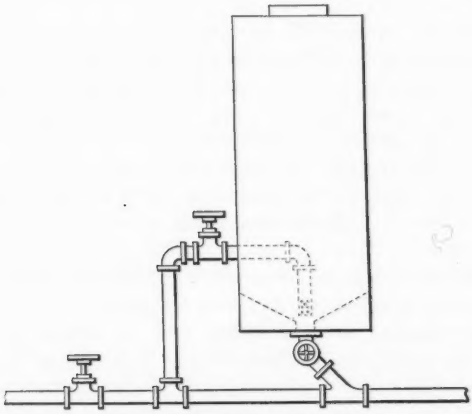
The plant, after being moved to Forty-second Street and East River, was entirely rearranged, and in such a way as to obtain much better results than those obtained previously. The size of the pipe from the condenser to the blasts was increased to $1\frac{1}{2}$ ins., and a much greater pressure was obtained, thereby largely increasing the quantity cleaned. The tanks were about 200 ft. from the power-house. The arrangements for drying and storing sand ready for use were also improved, and the handling was facilitated considerably by the use of the crane in lifting and piling the steel.

Two plants are at work: That for The Degnon-McLean Contracting Company consists of four tanks of double-row, riveted, extra

Mr. Belzner. heavy, ordinary kitchen-boiler, 14 ins. in diameter and 4 ft. 10 ins. long, the interior arrangement of which is shown in Fig. 4. The plant in use by the Holbrook, Cabot and Daly Contracting Company consists of two tanks having a similar interior arrangement.

Although four tanks were erected for The Degnon-McLean Contracting Company, only two are in use, as a rule, the extra tanks being kept in reserve in case of any trouble, thereby preventing any interruption of the work.

The simplicity of the design of these sand tanks should recommend itself to engineers, because any mechanic can look after them, thus avoiding the use of patented devices such as described by Mr. Lilly.



SECTION OF SAND-BLAST TANK.
FIG. 4.

Great care has been taken in the selection of the sand. That coming from the shores of Long Island Sound has proved to be the best for the purpose desired. The arrangements made for drying the sand consist of an open brick flue, about 3 ft. wide and 20 ins. high, on which are placed two iron trays. These trays are of $\frac{1}{4}$-in. iron, and each is 6 ins. deep, 3 ft. 6 ins. wide and 4 ft. long.

Great care should be taken in drying the sand. It should be turned over continually, which in this case had to be done by hand. When dry it should be removed from the pans at once, and not allowed to burn or bake, for in that case when it came into impact with the steel it would be brittle, and, battering into fine dust, would not remove the rust. Sand dried properly and carefully can be used two or three times with good results. In a permanent plant, a rotary dryer, over a fire, or supplied with a hot blast, could be used very economically, and the drying would be more uniform.

Mr. Belzner.

A section, about 6 ins. in diameter, was cut out of the crown of each blast tank and a screw cap fitted to the opening. This is removed while the tanks are being filled. The sand is passed through a fine wire mesh before being poured into the tanks, so that nothing can pass through that will tend to choke or obstruct the valves and fittings.

The outlet for the sand is at the bottom and center of the tank, and is of 1½-in. pipe connecting below with the air-pipe at an angle of about 45 degrees. About 6 ins. above the outlet another connection is made through the side of the tank by a 1-in. pipe extending to the center of the tank, with an elbow, the end looking down into the outlet. This pipe and elbow are perforated with small holes, and air under pressure, and controlled by a valve, is admitted so as to keep the sand slightly agitated, thereby facilitating its flow through the outlet.

The sand flows from the tanks through a flexible rubber hose of 2½ ins. internal diameter, to the end of which is attached an ordinary pipe reducer to receive the nozzle; it passes out at a uniform pressure of 65 lbs. per square inch. This pressure is furnished from the power-house erected for the purpose of supplying power for the work being done on Park avenue and Forty-second Street.

In front of the tank a platform of 2-in. timber, 25 x 50 ft., was built. On this the pieces of steel are placed side by side, and when the upper sides are cleaned, the pieces are turned over and the opposite sides cleaned. When cleaned, the steel is painted, and then removed and piled by the crane.

Nozzles of extra-heavy, ½-in. gas pipe, varying from 7 to 18 ins. in length, have been used; but it has been found that the 12-in. lengths are most effective. The life of the nozzles varied with the sharpness of the sand, the temper of the pipe material, and the air pressure, but, on the average, lasted 1½ hours. The nozzles were generally worn through, about 2 to 3 ins. from the reducer, owing to the deflection of the sand leaving the large hose, passing through the reducer and then striking the nozzle at that point. This condition would suggest that a special, graduated coupling from hose to reducer be devised, so that the sand would pass through at a uniform rate without meeting a break, thus avoiding the deflection.

The force consists of a foreman, who regulates the valves controlling air and sand, two nozzle-men who direct the blast (these men had to wear goggles to protect their eyes), two men to dry the sand, attend to the fire and keep the tanks filled, and also, one laborer, who assists the nozzle-men in handling the hose.

As the yard covered a large area and the steel was distributed all over it, it was a question whether it would be more economical to have a portable blasting machine or to make it stationary and use the crane and traveler for the purpose of handling materials. It was finally de-

Mr. Belzner. cided to make the plant stationary and use the crane for collecting and subsequently piling the steel.

The material cleaned consists principally of bulb angle-columns, I-beams for wall-columns, roof I-beams, knee-braces, rivets, plate-girders, splice-plates, grillage-beams, and angles. Plate XXXVI shows a girder before and after being cleaned by the sand-blast.

The question of the advisability of cleaning the steel before it leaves the shops could well be taken up. Were the mill scale and dirt removed before the steel is painted, the protective coating given it at the shops would undoubtedly prove more effective in the prevention of corrosion than by the present methods.

Such an adjunct to the manufacturing plants, if properly laid out, could resolve itself into practically first cost. If automatic devices for drying the sand and then feeding it to the blast were devised, much labor and time would be saved. Still more, the nozzles of the blast could be in a fixed position, and a rolling table provided for the steel. An automatic device for spraying the paint on the steel might also prove an advantage.

In preparing this discussion the speaker had the assistance of Mr. R. S. Fowler, Junior Assistant Resident Engineer, who also furnished the data, photographs and drawings. The speaker's thanks are also due to Mr. J. J. Shannon, Inspector for the Rapid Transit Subway Construction Company, for useful suggestions.

Mr. Paschke. THEODORE PASCHKE, M. Am. Soc. C. E.—Before giving any figures which can serve as a basis for comparison with those given by Mr. Lilly, as to the cost of cleaning some of the structural steel for the New York Rapid Transit Subway, as described by Mr. Belzner, it will be necessary to state briefly and as nearly as possible the actual conditions, rather adverse in some cases, under which the work had to be done.

When it became evident that the shop coat of paint had been practically destroyed by long exposure, and that it was necessary to arrest the destructive work of corrosion which had set in, the Subway Construction Company, in obedience to orders from the Rapid Transit Commission, assumed the responsibility of the work, and arranged with its sub-contractors on Sections Nos. 2 and 3 to perform the work of cleaning the steel and replacing the shop coat of paint, as an extra, at cost plus the usual percentage allowance customary in such cases. The sub-contractors for Section No. 2 (comprising the Elm Street section) are the Degnon-McLean Contracting Company; for Section No. 3 (comprising Lafayette Place and Fourth Avenue) the Holbrook, Cabot and Daly Contracting Company. The work was done by them subject to the inspection of the engineers of the Rapid Transit Commission.

The work was started by hand cleaning, that is, by hammer,

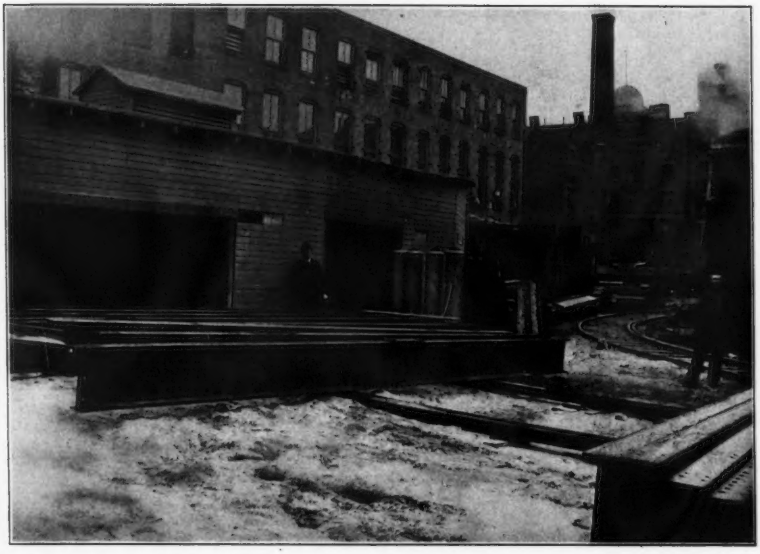


FIG. 1.—FIFTEEN-INCH I-BEAM, BEFORE BEING CLEANED WITH THE SAND-BLAST.



FIG. 2.—FIFTEEN-INCH I-BEAM, AFTER BEING CLEANED WITH THE SAND-BLAST.

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scraper and wire brush. This did not prove satisfactory either in point of cost or in efficiency, and involved the sub-contractors in an almost continuous controversy with the inspectors. It was suggested that the sand-blast process be used, and in view of the fact that the sub-contractors had compressed-air pipes along the line of their work, thus facilitating the installation of such process, Mr. Deyo, Chief Engineer of the Subway Construction Company, readily assented. Mr. Paschke.

On the Elm Street section the steel to be cleaned was piled at various points along the street. Mr. Belzner has described the attempts made to locate the sand-blast at the various piles of steel. Thus, the operation of the blast had to be confined to one point and carried on during night hours. The steel had to be brought to the sand-blast, and there manipulated by hand entirely. The arrangements for drying the sand were primitive, owing to the temporary conditions of the work. The first cost of installation of the blasts, their various removals and transfers from one point to another, was added to the cost, tending to increase this abnormally.

At the Forty-second Street yard, where the Fourth Avenue steel was piled, the conditions were somewhat different. The yard is 200 ft. wide and 700 ft. long, and is provided with a network of tracks and a traveling crane with a flat car for the handling of the steel. Here, a plant on a little more permanent basis was erected, and the steel handled and brought to it from the various points of the yard by the traveling crane. Although these conditions were more favorable than on Elm Street, they may be considered rather exceptional for such work.

In the work on Elm Street and at the Forty-second Street yard about 5 000 tons of steel have been cleaned by this process.

But all this steel was not cleaned over its entire surface; only about one-half being cleaned entirely, one-quarter had 75% of its surface cleaned, and on the other quarter about 50% of its surface underwent the sand-blast process, for the reason that on the remaining surface the shop coat was found to be in good condition.

In the case of the work at the Forty-second Street yard, the total cost, including the repainting, amounted to from $3.50 to $6.50 per ton, the higher cost being due to the greater adversities experienced during the winter months. In the case of the work done on Elm Street, the cost ranged about $1.50 per ton higher. It should be stated that the eight-hour basis for a day's work is in vogue throughout the subway work, and that the entire work of cleaning and painting had to be conducted in the open, exposed to all the vicissitudes of the weather, resulting often in the necessity of reblasting the steel, before being able to paint it.

It would seem from these figures that in the case under consideration the use of the sand-blast did not result in any direct economy

Mr. Paschke. over hand cleaning. However, the results obtained were infinitely superior. The steel, after emerging from the sand-blast, presented a beautiful appearance, in fact, being fit to go into an electro-plating bath.

The experience had here with the usual customary shop coat as a protection for the steel against corrosion before erection seems to confirm Mr. Lilly's contention for the desirability of applying the sand-blast to structural steel at the works, after manufacture and before the application of the shop coat. Notwithstanding the high cost of the work performed in the present instance, which was due to exceptional and rather abnormal conditions, the speaker fully believes that the sand-blast process can be used at the works to advantage, and at a cost not exceeding that given by Mr. Lilly.

Mr. Sabin. A. H. SABIN, Assoc. M. Soc. C. E.—Although the speaker has never actually conducted any sand-blast work, he believes that it was at his suggestion that the sand-blast was used upon the One Hundred and Fifty-fifth Street Viaduct some years ago. He has, however, been interested for years in this matter of the proper cleaning of structural steel before painting, and can agree fully with what Mr. Lilly says about its great importance. It is a waste of money to buy even the best of paint and spend a large sum for labor in applying it to a rusty surface.

More than a hundred years ago, one of the great early English engineers—Smeaton—remarked that he had observed that if rust had once started on the surface of the iron, it made no difference what varnish or paint was applied to the surface, the rusting would continue to go on progressively under the paint. That conclusion has been reached by every man who has investigated the subject honestly and disinterestedly.

Mr. Paschke has stated when the steel had been cleaned with the sand-blast it was fit to go into an electroplating bath. That is right. It will be observed that it is assumed that if a piece of metal is to be electroplated it has to be clean, down to the surface of the metal; none of the oxide or scale must be left on the surface. It is equally true that to apply a vitreous enamel, such as on granite earthenware, etc., in the first place the surface of the metal must be obtained on which to put the enamel. All such ironwork is cleaned usually by pickling. To apply a varnish enamel, as in the case of a bicycle frame, it is absolutely necessary to do the same thing; otherwise the enamel, or the electroplate, will come off in time, because the rate of expansion of the scale is always a little different from that of the iron, and in time the scale will loosen up.

Now, the speaker is a paint man, and has had an experience of a good many years. He believes that paint sticks on iron in exactly the same way that anything else does, and the conditions which favor the

adhesion of other things favor the adhesion of paint. If it is necessary, if it is absolutely indispensable, as all agree, to have all these other coatings applied to the actual surface of the metal, and not to any scale or rust, or anything of that sort, it is also desirable to apply paint directly on the iron. Mr. Sabin.

There are plenty of people who think—no doubt many who think honestly—that the oil and paint will mix up with the iron rust and keep out the air, and in that way the corrosion will be stopped. The trouble with that theory is that the paint and varnish are not absolutely non-porous. If they were it would be all right. Neither is cement or concrete non-porous, and when the corrosion gets under way, its action is very rapid. That is a chemical question which is not worth while discussing now as it has been beaten over a good many times, and probably most of those who are interested in the subject are thoroughly familiar with the theory of the matter.

It is comparatively easy to keep iron free from rust when it is clean, but, after the rust has started, it is very difficult to stop it or to clean it away from the metal.

The speaker had hoped that this paper might bring out a discussion from somebody who had had experience in cleaning iron by dipping it in acids, or "pickling." Of course, that is not sand-blasting, but the result is what is desired. The speaker is not aware that, in this country, any structural metal-work has been cleaned by pickling, but a great deal has been cleaned in Europe, some of it many years ago, and it is being done now, with most excellent results. Of course, the result of a first-class job of pickling is just the same as the result of sand-blasting.

One of the advantages of the sand-blast, not mentioned by Mr. Lilly, is that it leaves the iron not only clean, but dry. The process of pickling leaves the surface of the iron wet, and it has to be dried. It would be difficult to apply the process of pickling to structural work in place, such as an erected bridge, or anything of that sort, but it would have been extremely interesting to have had an idea of the comparative cost of cleaning the steel for the rapid transit work by pickling, as compared with the sand-blast.

There is probably a thousand times as much iron and steel cleaned by pickling as is cleaned by the sand-blast. There is an immense amount of it done. Those who are not familiar with the subject have no idea of the extent to which it is practiced, but, in this country, it has not been applied to structural steel.

There is a feature which did not appear in Mr. Snow's admirable discussion. Mr. Snow has really had a great deal of experience in the use of the sand-blast on bridges, and has told the speaker that, usually, he did not clean the whole of a bridge with the sand-blast, as that is regarded as rather expensive. Such parts of the bridge as are

Mr. Sabin. specially liable to corrosion are cleaned by the sand-blast, and other portions, which are not so subject to deterioration, are cleaned in a less thorough and less expensive manner, for the reason that those portions which are most liable to corrosion will, in spite of the greatest care that can be taken, probably rust out as rapidly as the other portions with somewhat less care, although, of course, a man who is sufficiently interested in the matter to do sand-blasting is not going to have any poor work done. This feature, however, is worth remembering.

It may be regarded in another way. If a man sets up a sand-blast plant to clean a bridge, and has all his apparatus and his gang of men to do it, and only cleans, say, one-quarter or one-third of the bridge, he cannot do that quarter or third of the bridge as cheaply per square foot as he could clean the whole bridge, so that the cost per square foot is a great deal higher than it would be if he were cleaning the whole work, and for that reason any figures that he gets must be taken with regard to that fact.

In reference to the possible danger of cutting away the iron: Mr. Lilly observed that it was immensely more difficult, and required a great deal more power, to remove a hard compact scale than to remove ordinary rust. Now, the difficulty of cutting away tough, hard steel is immensely greater than that of cutting away the hardest kind of rust, and the speaker was told—this was not his own experience—by the manager of the Wolff Bicycle Company, some years ago, when they were using the sand-blast for cleaning the frames of bicycles, that before they purchased their sand-blast apparatus, they were apprehensive about cutting away the metal, because the tubing they used was very thin; and to test the matter they held a piece of tubing in the current from the sand-blast machine for twenty minutes continuously and then, with a micrometer scale caliper, which would show a thousandth of an inch, were not able to find any diminution in the diameter of the tube. Consequently, they thought that they were safe in using it; and if that is the case, there should not be very much apprehension as to cutting away the steel.

Mr. Seaman. H. B. Seaman, M. Am. Soc. C. E.—There seems to be little to add to the discussion which has already taken place, except, possibly, to mention the dangers of the misuse of the sand-blast. It is undoubtedly a most efficient method of cleaning iron, especially where the rust is badly caked, or is in inaccessible corners and cannot be reached by hand; but where the rust is slight, and especially where surrounded by elastic paint, the excessive use of the sand-blast may prove more injurious than the rust which it removes. The sand-blast will remove the rust quickly, but if continued long enough to remove the elastic paint, which requires considerably more time, the parts which were rusted will be worn deep and pitted, and when the whole surface is bright and

smooth, and acceptable to an enthusiastic inspector, more metallic iron may have been removed than would be the case after several ordinary coats of rust. Furthermore, the naked iron, as left by the sand-blast, will rust much more quickly than when the mill finish is left. Mr. Seaman.

An illustration of the danger of overdoing the sand-blast occurred recently, under the supervision of an ardent, but well-meaning, inspector. Four columns, which had been similarly exposed to the weather while stored in the same pile awaiting erection, were brought out and laid side by side to be cleaned by the sand-blast. After 3½ hours of the sand-blast two of these columns were stripped absolutely clean of rust and paint, and of all sign of the original mill surface; finished, in fact, clean enough for electroplating. The work could not have been done more thoroughly if performed in a laboratory for experimental purposes. The remaining two columns were then cleaned of rust and dirt, but all good paint was left on. This required 45 minutes, and the columns were left in better condition than the first two, at about one-fourth of the expense.

The theory that iron must be cleaned to a white surface before being painted does not seem tenable. The thin coat of black oxide formed after rolling is of itself a valuable protection, being the most permanent form of iron oxide, and even when the iron is tinted brown with rust it is not clear why the paint which would protect the iron from rusting, will not in like manner prevent the rust from progressing, excepting, of course, where the rust is so thick as to prevent adhesion of the paint to the iron. Where the sand-blast is used it is necessary to paint at once to prevent corrosion.

Aside from the commercial or scientific value of sand-blasting, there is a very serious question of its effect upon the eyes and lungs of the operator. Its use in connection with bridge shops would seem, not only objectionable on account of its disturbing effect upon the other operations, but, as already mentioned, would remove the black oxide of manufacture, which is its natural protection. Any scale which may be formed after rolling is quite thoroughly removed in punching and handling through the shops.

E. A. H. Tays, M. Am. Soc. C. E. (by letter).—The writer has noticed that the means of drying the sand, as described by Mr. Lilly, were very crude, and the idea suggested itself that they could be improved. Mr. Tays.

The following suggestions may be of service in enabling those of the profession engaged in that work to improve upon the present practice in that line.

Where temporary plants are required, a sheet-iron bed, 8 ft. long, 4 ft. wide, or wider, made hollow, about 4 ins. high, or, with sufficient room for a 2-in. steam coil, or line, of pipes, set on a frame 3 ft. high, would do the work; the steam coil being used to pass the exhaust

Mr. Tays. steam through; or, the exhaust could be turned directly into the hollow bed. This bed can be made of the thinnest sheet or galvanized-iron, and should have a 2-in. flange on the sides, but none at the ends; and it might be set with a slight fall, to facilitate drawing off the sand with a hoe or rake at the lower end.

In large, stationary plants, a cylindrical dryer, on the lines of the Howell-White roaster, or of the type of the ordinary ore-dryer used in dry-crushing mills, would seem to be just about the thing. It could be made of much lighter material than the ore-dryer and much smaller in size.

This dryer is a revolving cylinder, larger at one end than at the other, and is heated by wood or coal, the heat passing down the cylinder. The sand is fed into a hopper at the small end, and the revolutions of the cylinder, say five per minute, gradually pass it out at the other, thoroughly dried.

These observations may enable some of those who are working in this line to devise an economical as well as efficient sand-dryer; if so, the object of these remarks will have been attained.

Mr. Lilly. GEORGE W. LILLY, Assoc. M. Am. Soc. C. E. (by letter).—Mr. A. H. Sabin has called attention to the fact that one of the great advantages of the use of the sand-blast is the dry condition of the metal after being cleaned by it. This is certainly a great advantage and essential to the best efficiency of the preservative paint. It is also true that, unless the paint is applied soon after the cleaning is done, moisture is likely to accumulate on the steel, especially if the atmosphere is nearly or quite saturated with moisture. It has been urged, therefore, that the paint should be spread within the shortest possible time after the cleaning is done, and in no case should any cleaned surface be permitted to remain over night without a coat of paint upon it. Some delay, say 2 or 3 hours, may be permitted when the atmosphere has only slight humidity. When the atmosphere is surcharged with humidity the moisture may gather on the steel immediately after it is cleaned. At such times no cleaning or painting should be done.

While, as Mr. Snow says, it may be considered no disadvantage to have some sand get into the raw paint, if it is to be subjected to the blast action of locomotives; yet screens are sometimes of advantage to prevent too large a quantity of sand getting into the paint in the buckets before it is applied to the steel. At times the wind may send large quantities of sand back to the painters and the paint become so filled with sand that it rolls under the brush and cannot be spread properly. It is not often found necessary, however, to use the screens between the nozzle-men and the painters.

The writer admits freely that neither the pan nor the hopper form of sand-dryer is scientific or highly efficient. A rotary dryer is, no doubt, a good form, where power is available and the exhaust steam

may be utilized; but, at Columbus, Ohio, the power was from 1 200 to 2 100 ft. from the places where the cleaning was done. No doubt, a better sand-dryer can be devised than any of those which have been used in the work done heretofore. Mr. Lilly.

Mr. Seaman urges caution against the danger of extending the use of the sand-blast too far and cleaning steel which is already in good condition to receive the paint. The same thought was suggested in the paper, and it is certainly true that good judgment should be exercised. The intelligent application of the process in the cases where it is required to prepare the surface of the metal so that the paint, when applied, will adhere properly and give good protection against further corrosion is all that is contended for. For the reason that some of the paint was still good, some parts of the viaducts named in the paper were not sand-blasted down to the metal surface, but rust spots only were cleaned away. The parts where rust and corrosion have destroyed the paint, and where the paint is dead and disintegrating, should be cleaned thoroughly; and the sand-blast seems to be the best process for such purpose.

The black or magnetic oxide spoken of by Mr. Seaman is nearly all destroyed by the rusting of the metal before the shop work is completed, save, perhaps, where the thicker scale has formed. That all the mill scale is removed by the processes through which the steel passes in the shop is, the writer believes, putting the case rather too strong.

Mr. Fowler suggests permitting the metal to rust somewhat, in order to remove scale as far as possible, and then cleaning it thoroughly before painting. It will be observed, if a careful examination of old structures be made, that in many cases the mill scale has been covered with paint, and corrosion has attacked the steel and loosened the scale, making centers from which rust will extend.

The composition of mill scale, or, at least, of its characteristic, porous inner layer, makes it reasonable to expect just such results. Mill scale forms in two layers, the inner one being represented approximately by the formula $6\,Fe\,O + Fe_2\,O_3$, and, as stated, is very porous and brittle. The outer layer contains a larger but varying proportion of $Fe_2\,O_3$. The air and moisture contained in this porous scale tend to destroy the paint spread over it by starting corrosion. This scale is magnetic. A galvanic action is said to be set up around the edges, and corrosion commences there and afterward extends under the scale and outward under the paint. It is considered important, therefore, that the mill scale be removed by some efficient means before the first coat of paint is applied.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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NOTE ON THE COEFFICIENT OF ELASTICITY OF CONCRETE AND MORTAR BEAMS DURING FLEXURE.

Discussion.*

By E. J. McCaustland, Assoc. M. Am. Soc. C. E.

Mr. McCaustland.

E. J. McCaustland, Assoc. M. Am. Soc. C. E. (by letter).—It is quite evident, from a study of the tests on concrete and mortar beams reported by Mr. Falk, that, in so far as they prove anything, they prove that the coefficient of elasticity of concrete or mortar does not increase materially with age. However well established it may be that the strength of mortar made from Portland cement increases with the lapse of time, it is not established anywhere, as far as the writer is aware, that the coefficient of elasticity is affected in a like manner. For the practical purposes of the engineer, it is of more importance to know the properties and to be able to forecast the behavior of mortar and concrete during the earlier stages of the hardening process. This is the critical period, in many classes of work, when loads must be borne by the structure before time is given for an advanced degree of hardening. Nevertheless, all reliable information regarding this important structural material is worthy of record.

These tests are of interest, and afford valuable information, despite the fact that the varying mixtures give no opportunities for comparison, or for average results. This lack of comparison leaves many

*This discussion (of the paper by Myron S. Falk, Jun. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

points unexplained. On the face of the record there seems to be no good reason why the beam D should show a fiber stress 24% lower than the beam B which contains the greater proportion of sand, and hence, theoretically at least, should be the weaker of the two. The extremely low coefficient of elasticity of the beam D, as determined by the tests on the half length, is also unaccounted for. Mr. McCaustland.

Beam A is not reported, as to the full-length test, but the different values of the coefficient of elasticity for A_1 and A_2 might be accounted for by slight errors in reading the deflections. The figures for fiber stress show close coincidence. With the beam B there is a wide variation in the coefficient of elasticity determined from tests on the two ends. Why the elasticity of B_1 should be 100% greater than that for B_2, is not clear. Beams C and D in all cases show lower values for the elasticity for the second tests, while the fiber stress does not differ widely from the value obtained in the first test.

The coefficient of elasticity is computed properly for the elastic deformation only, since the inclusion of the total deformation in any case would give a false idea of the properties of the material. However, the amount of this total deformation is a matter that should be taken into consideration, practically, since a mass of concrete under stress changes its character, more or less, during the earlier stages of the loading, and subsequent tests may show materially different results from the initial. The intrinsic properties of the mass do not change, but there is, no doubt, a rearrangement of the molecules and a redistribution of the initial stresses, which are due to hardening, which may leave the mass more compact and solid, but, whether stronger or weaker than before, depends upon the care taken in fabrication and ramming in the moulds, as well as upon the percentage of water used and the conditions attending the process of hardening. It may be of interest to compare the results with those obtained from neat-cement mortars of other brands, and hence the following data are presented.

Table No. 2 gives a record of results obtained by the writer from flexural tests of a number of neat-cement mortar beams made to determine the ultimate fiber stress and the coefficient of elasticity. The beams were approximately 28 ins. in length, and $2 \times 2\frac{3}{4}$ ins. in section. They were moulded in the spring of 1902 by Mr. H. B. Stevens, a student in the College of Civil Engineering of Cornell University, and were used in determining the time of initial and final set of mortar. Briquettes of the same mortar were made in order to test the effect of varying proportions of water on the tensile strength; but Mr. Stevens' investigations did not warrant any general conclusion. The beams, therefore, when tested, were about one year old, and had been kept, after hardening in air, in the College laboratory, at a temperature of about 65° Fahr. Four of the beams were of Cayuga Lake Cement, a brand manufactured near Ithaca, N. Y., and only quite recently placed

Mr. McCausland.

on the market. The other three bars were of the well-known Empire Portland brand.

The span was uniformly 24 ins., and the load was applied at the center by increments of 20 lbs. Deflections were measured by a micrometer screw, reading to ten-thousandths of an inch. Readings were taken for the permanent deflections of the bars, after the application and subsequent removal of each successive load.

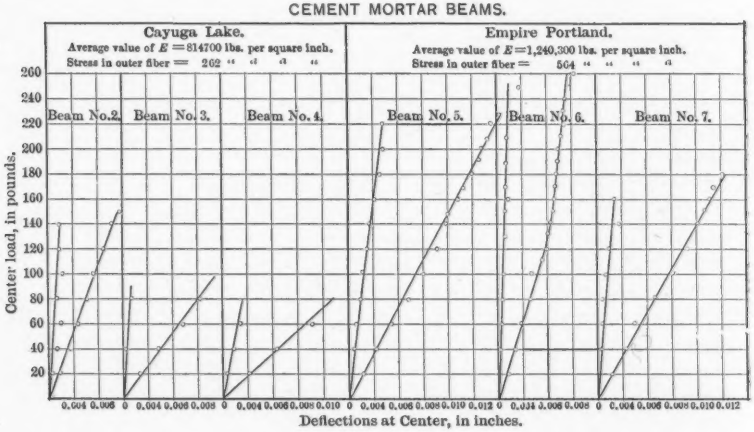


FIG. 2.

The diagrams on Fig. 2 show, as in Mr. Falk's experiments, the curves of permanent and elastic deflection; the intercept between these two curves at any load is the value taken for the deflection from which to compute the coefficient of elasticity. On Beams 2, 3 and 4 the value of E, the elasticity, was computed for central loads of 80 lbs., while for Beams 5, 6 and 7 the central load was 120 lbs.

TABLE No. 2.

Span=24 ins. Load at center. Age of beams=1 year.

No.	Brand.	Percentage of water in mixture.	Time of Set, in Minutes.		Section of Beam, in Inches.		Coefficient of elasticity, in pounds per square inch.	Extreme fiber stress in pounds per square inch.
			Initial.	Final.	Width.	Depth.		
1	Cayuga Lake.	23	130	230	2	2.75	.....	571
2	" "	24	180	230	2	2.75	1 384 000	357
3	" "	25	180	235	2	2.75	600 000	238
4	" "	26	175	300	2	2.75	460 000	190
5	Empire Portland.	20	120	250	1.94	2.62	1 219 000	623
6	" "	30	235	360	2	2.75	1 582 000	618
7	" "	31.8	190	305	2	2.75	920 000	452

Mr. McCaustland.

It is quite noticeable that the values of the coefficient of elasticity and the extreme fiber stress for the Empire Portland beams range fairly close to those recorded by Mr. Falk, although these are of neat-cement mortar instead of a mixture of 1:2 or 1:3. It is possible, but scarcely probable, that a greater age in these beams would have developed a greater strength and a greater degree of stiffness, with a consequent rise in the value of E.

It is submitted, however, that these tests, like many others reported in various papers, are altogether too few to warrant definite conclusions. The percentage of water used and the extreme fiber stress seem to vary inversely, but this is by no means an established relation, except possibly for certain extremes. There is here a field for a very definite and extended series of experiments with standard American brands of cement.

In addition to the preceding—not in the form of a discussion, but as new matter more or less related—the results of certain tests on concrete and mortar columns are here presented.

These columns were constructed by the writer in February and March, 1900, in the laboratories of the College of Civil Engineering at Cornell University, where they were tested, under the direction of Professor C. L. Crandall, M. Am. Soc. C. E., with Mr. O. A. Johannsen, Instructor in Civil Engineering, in direct charge of the work.

The cement used was Alpha brand, taken from a fresh supply provided for use in the cement laboratory work of the college. The usual tests did not show any abnormal qualities. The sand was a clean, fine, and not especially sharp, bank sand from Fall Creek. A careful test of the sand grains determined that the size of 60% of the total weight was less than 0.081 in., while 10% was less than 0.044 in. Adopting Hazen's method of recording sizes of filtering sands, the uniformity coefficient is 1.84. The stone used was sandstone, varying in size from $\frac{1}{2}$ in. to 2 ins.

The columns were circular, 10 ins. in diameter and 40 ins. long, constructed in wooden forms made of narrow staves held together by yokes, which served the purpose of hoops. The cement and sand were mixed dry and the stone added. The least possible quantity of water was used, so that when the forms were rammed full, very little moisture appeared on the surface, and there was no quaking of the mass. The forms were removed after 24 hours, and the columns remained in the basement of the College building until tested.

The temperature of this basement did not vary at any time widely from 65° Fahr. The columns were watered at interwals of about four days until three months old, after which no water was applied. The tests were made on a Riehlé 400 000-lb. machine, and shortenings were read from micrometer rods placed between yokes held to the column by

Mr. McCaustland.

set-screws. Two rods, on opposite sides of the column, were provided, and contact was determined by an electric bell. At times the micrometers read widely different on opposite sides of a column, probably due to local weaknesses, but in all cases the mean of the readings was taken from which to determine the amount of shortening. The initial load was taken throughout as 1 000 lbs., which gave a unit stress of 12½ lbs. per square inch. On all columns, except Nos. 2, 4 and 5, the loadings were repeated five times before advancing to higher values, the micrometers being read at each application and release.

The diagrams on Fig. 3 show the stress and strain curves under the first loadings and also after a repetition of the loads, together with the permanent-set curves for the same conditions. The coefficient of elasticity is computed for the elastic deformation at 500 lbs. per square inch, except for the three mortar columns, Nos. 17, 18 and 19, which are computed at a load of 1 000 lbs. per square inch. The reason for the abnormal set shown in Column No. 3, with the accompanying high coefficient of elasticity, is not clear, and the mean value of E for the 1:2:3 mixtures is determined by using the values derived for Columns Nos. 1, 2 and 4 only. The 1:3:4 group gives fairly uniform results. The 1:3:5 mixture gives less uniform results, but is still within reasonable limits.

Owing to the slipping of the micrometers on Column No. 10, the stress and strain diagram for this specimen could not be plotted. This was true, also, of Column No. 16, of the 1:2:5 group. Column No. 13 gives an unusually low, as No. 14 gives a high, value of E, but these wide ranges of value are almost certain to develop in tests upon low concrete specimens in which the aggregate bears such a large proportion to the total volume. Where the matrix (cement and sand mortar) is but slightly in excess of the volume of voids in the aggregate, it is almost impossible to get a homogeneous mixture and to preserve the homogeneity of the mass while it is being placed in position and rammed. Segregation is bound to occur, with resulting abnormal qualities, as made evident by many tests.

The low unit stresses developed by the 6-in. cubes are no doubt due to the difficulty in moulding such a small block of fairly representative material. The writer believes that concrete cubes for crushing tests should never be less than 8 ins. on edge, and, preferably, 12 ins. There is a wide difference between the results obtained from crushing tests on 12-in. and on 6-in. cubes made from the same batch of concrete. Any form of test, on a concrete specimen, loses in value, unless the specimen can be assumed, without question, to be fairly representative in character. Hence, two general principles should govern in the preparation of the material for testing:

First.—Acquire and place on record a complete and comprehensive knowledge of every item which might determine or affect the physical

Mr. McCaustland.

Fig. 3.

Mr. McCaustland.

or mechanical properties of the specimen. Character, composition, quality and form, as well as proportions and methods of fabrication, should form an important part of the history of a test specimen.

Second.—Keep in mind the practical limitations of commercial use, and avoid, if possible, the wide gaps which too often exist between laboratory results and those which may reasonably be expected in the field of "first-class work."

TABLE No. 3.

Proportions.	No.	Age at test, in months.	Load at failure, in pounds.	Area, in square inches.	Ultimate unit stress, in pounds per square inch.	Coefficient of elasticity, at 500 lbs. per square inch.	Average unit stress on 6-in. cubes of the same material.
Cement 1, sand 2 and broken stone 3.	1	14	79 300	79.3	1 000	1 050 000	
	2	11	143 000	81.7	1 752	1 530 000	
	3	13	98 300	80.8	1 215	3 060 000	1 751
	4	14	212 000	79.3	2 650	2 010 000	
Cement 1, sand 3 and broken stone 4.	5	10	120 000	80.8	1 484	1 100 000	
	6	11	114 000	82.5	1 382	1 380 000	
	7	14	98 000	79.3	1 230	1 425 000	1 432
	8	11	126 600	81.5	1 550	1 441 000	
Cement 1, sand 3 and broken stone 5.	9	14	126 400	81.5	1 550	1 450 000	
	10	14	120 000	80.0	1 500	Not determined ...	1 092
	11	14	146 400	81.5	1 792	1 531 000	
	12	14	90 000	76.8	1 170	1 050 000	
Cement 1, sand 2 and broken stone 5.	13	15	85 000	81.5	1 045	840 000	
	14	15	180 000	83.5	1 955	1 510 000	
	15	14	118 300	81.8	1 450	1 372 500	1 090
	16	23	137 000	81.0	1 680	Not determined.	
Cement 1, sand 4.	17	23	215 000	81.0	2 660	2 775 000	
Cement 1, sand 2.	18	23	273 230	81.0	3 410	4 625 000	2 895
Cement 1, sand 3.	19	23	180 000	81.0	2 250	3 700 000	1 861

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE PANAMA CANAL.

Discussion.*

By Messrs. W. E. Crane, Boyd Ehle, William H. Burr and George S. Morison.

Mr. Crane.

W. E. Crane, Jun. Am. Soc. C. E.—That part of the discussion relating to the Pacific terminal of the canal has interested the speaker very much, and he would like to suggest to the author that it should be discussed further.

The length of the canal is approximately 43 to 45 miles, and the coastal plain on the Pacific Coast is about 6 miles in width. It may be assumed that the distance thus taken is measured from mean high water on the Pacific Coast to mean high water on the Atlantic Coast. The City of Panama is situated on a point, and its elevation is but a few feet above the Pacific Ocean. At extreme low tides, there is exposed a mud flat extending into the ocean 3 to 5 miles, possibly a greater distance. Coast line vessels anchor near the three islands which are from 4 to 5 miles from the Panama dock. The terminal of the canal is about 2 miles along the shore above Panama.

The speaker visited this section of country in 1896, and remembers a discussion, on the day he was at this terminal, relating to the direction and distance from the shore line to deep water, the width and depth of excavation, and the method proposed for protecting the banks, the probable cost of this section, what action the winds and waves would have on the banks of the canal, and how much dredging would be required annually in this section of the canal.

*Continued from March, 1903, *Proceedings*. See January, 1903, *Proceedings*, for paper on this subject by George S. Morison, Past-President, Am. Soc. C. E.

Mr. Crane. Mr. Harrison has mentioned this portion of the canal, but only as to the depth advisable to permit vessels (especially war ships) to enter the canal at extreme low tide.

A further discussion of the Pacific terminal, by members who understand the conditions and have had access to the plans and estimates, would be very interesting and beneficial.

Mr. Ehle. Boyd Ehle, Assoc. M. Am. Soc. C. E.—As usual, Mr. Morison, in his statement of facts, has left little to be said. In the discussion, however, certain statements have been made which do not agree with the speaker's knowledge of actual conditions observed on the Isthmus at various times in years of service on the surveys and canal work.

The Chagres is not subject to great scouring action, and there cannot be many of the dangers predicted regarding the silting up of the channel. Above Alhajuela the Chagres is simply a mountain stream, running part of the way through rocky gorges. The soil is not a lava ash, as has been assumed, but is a clay held in place by the rank vegetation of the tropics. Below Alhajuela and nearer to the canal location there is some alluvial soil, but of no great extent, and this, in the case of a lock canal, would form part of a lake bottom, and would not be affected by the slight current to which, in Lake Bohio, even the great floods will be reduced.

Although the lock plan provides a certain solution of the flood problem, by the use of the Gigante Weir, the question is often asked, "Why not divert the Chagres to the oceans"? This was examined closely enough by the Panama Canal Company to show that there were no evident possibilities in that line. Surveys were made to find the shortest tunnel line possible, but the results gave no hope of anything feasible and economical, and the idea was abandoned.

The Tiger Hill cut-off undoubtedly has some merits not possessed by the river line, and these, as stated by Mr. Morison in a preliminary way, will lead probably to its thorough examination in the future. It could not be incorporated in the careful and conservative report of the Isthmian Canal Commission, it is said, on account of the lack of data. This will not be against it in a future study, and its merits and disadvantages will no doubt be weighed properly by the Commission before actual construction is started.

The solution of the canal problem by the construction of a sea-level canal has never appeared to the speaker as an engineering solution, as engineering is usually defined. There have never appeared to be any compensating advantages for such an excessive extra expenditure of money and time, and none appears to have been stated clearly and sustained.

Nature, through the tides, makes one lock necessary, and that, during most of the time, is the check on the canal's usefulness, as surely as more locks, provided they are in good order. The time gained in

doing away with the locks is insignificant in comparison with that required for the long journey around The Horn which the lock canal will save. It cannot have any recognizable value, as far as can be seen in the future. When it has such a value, probably canals will not be necessary, and the air, instead of the water, will be the highway of communication. It is true that locks are likely to be deranged, but should not, as an engineer's work, be likely to fail; besides, as a precautionary measure, the plans of the Commission provide for twin locks. Mr. Ehle.

The question of a sea-level canal is not an imminent one, as it is perfectly feasible to cut a lock canal to a sea-level canal at any time in the future, if so desired; and it can be safely left to the engineers of the future to decide whether a sea-level canal is required.

It seems that all the schemes for the control of the Chagres in relation to a sea-level canal were never worked out in detail. There was much procrastination on this problem by the French Company, and their tardy plan, after the failure of the first company, has never received any very enthusiastic encomiums from the engineers who have reviewed it.

A sea-level canal would be exposed to all the troubles produced by the great floods of the Chagres, with little chance for any protection. One scheme for the control of floods, however, would be the Tiger Hill location, which would take the canal out of the lowest part of the valley and into a safe position from Bohio to Colon.

The decrease in the height of the locks would seem to be desirable if contrasted with the loss of time incident to the operation of an extra lock, as a proper measure of conservatism, provided no serious difficulties were encountered in its construction.

Another point is that of decreasing the cost on the Pacific side by taking advantage of the rise of the tide. This would seem to be a proper utilization of Nature's forces--as much so as a switch-back over a mountain before a railway is built through it. Why not try it? A few hours of time are nothing compared with the days of steaming by the *Oregon*. When the demand becomes imperative, and the few hours saved would mean a proper return on the outlay, then build it as deep as such value will justify.

As to the case of a fleet, in the rare case of war, being at a disadvantage if divided by the fall of the tide, it appears that the enemy would be in as great trouble; however, that is a very remote contingency.

WILLIAM H. BURR, M. Am. Soc. C. E.—In this paper Mr. Morison has, among other things, set forth in deserving prominence some of the salient features of the Isthmian Canal Company's plan for the Panama Canal and his proposed modifications of them, which latter were also mostly, if not entirely, fully considered by the Isthmian Canal Commis- Mr. Burr.

Mr. Burr. sion. There is obviously a little delicacy in entering into the discussions in much detail which took place in the Commission regarding these or other matters, and it is the speaker's purpose to consider, as any member of the Society may, only the salient engineering features of the matter. It may be said with propriety that the shortened line between Bohio and Colon was considered carefully by the Commission, but only a limited examination was given to it in the field. This line is an old one, and was probably first proposed by Commander E. P. Lull, U. S. N. It possesses undoubted merits, and is worthy of careful consideration before final construction is undertaken, but in discussing this feature at this time two things are to be carefully borne in mind; the first is the incompleteness of the actual examinations made on this shortened route, and the second is the fact that a large amount of work has already been done on the French line between Bohio and Colon. It is hazardous to make an exact prediction of cost in the absence of necessary information on which to base it. Apparently, a comparatively small amount of money might possibly be saved by adopting the Lull line, but that cannot be stated confidently in the absence of complete borings and other requisite examinations. A serious, but not insuperable, objection is the considerable amount of embankment necessary between Bohio and Tiger Hill. These embankments may reach the height of 25 ft., and possibly a little more. While such embankments may be made safe, and are entirely justifiable under conditions such as those existing in connection with the Nicaragua route, they certainly are not desirable, and they should be avoided unless necessity exists for them, or adequate compensating advantages are attained.

Again, the adoption of this shortened line and the Tiger Hill locks involves the loss of time by a vessel traversing the canal necessary to make the additional lockage. As the gain in distance is only about 1¼ miles, the increased time required to pass the lock would be far more than that necessary to make the added distance by the French line. The introduction of the additional lockage, therefore, would be a sensible loss of time in passing through the canal, in fact, so great a loss of time as to increase materially the time of passage over that required by the adopted line. In other words, for the purposes of navigation, the canal would actually be lengthened by the Tiger Hill line and lock. The additional lock would also increase the opportunities of accident at the lock gates, with the added chance of destruction of the short Tiger Hill level by an accident at the Bohio gates suddenly releasing the lower-lock volume of water.

If the work of constructing the canal were to be begun as an entirely new project, it is not unlikely that the shortened line between Colon and Bohio without a lock might be preferable to that on which so much has now been completed. With the conditions actually

existing, however, it is the speaker's judgment that complete examina- Mr. Burr.
tions along the shortened or Lull line would show little or no difference in cost of completion.

It is true, as Mr. Morison states, that the locks planned by the Isthmian Canal Commission are larger than those which have ordinarily been constructed, and yet such locks as those built at Sault Ste. Marie save the construction of the Isthmian Canal locks from being violent departures from precedent, even with their material increase of lift. The massive masonry construction and other large features of these proposed locks would probably frighten few civil engineers, nor do they involve sufficiently difficult operations either of design or construction to make it necessary to incur the construction of extensive embankments to avoid them. It is not unlikely that many, if not most, engineers would prefer to avoid the embankments by resorting to locks of high lift.

It has been shown, in the discussion of a proposed plan for the Bohio Dam by Mr. Morison, that the consideration of seepage involves about as great uncertainties as can ordinarily be attached to engineering speculation, and, indeed, that no quantitative results can be predicted confidently in regard to it. Hence it is scarcely required to give detailed consideration to such a feature of the work. It may be stated, however, that it is not quite clear how the seepage under a dam at Bohio placed on porous material would be affected by the proposed Tiger Hill level. The total head between the surface of the water in Lake Bohio and that in the river-bed below the dam, or dam and canal, would remain unchanged, and as the seepage through such open and porous material would depend upon that head it could be modified only by the slightly lengthened seepage channel. The amount of seepage, therefore, cannot reasonably be supposed to be changed sensibly by this feature. Some recent experiences of the speaker, in connection with the seepage or flow of water through fine sand, or fine sand and silt, have impressed him in a marked manner with the danger attending the construction of a dam built on porous material, which he pointed out in his discussion on Mr. Morison's paper on "The Bohio Dam."

There are two other features of the modified canal plan brought out by Mr. Morison which may be treated largely as one, namely, decreasing the depth of excavation in the Culebra Cut by 3 ft. and the depth of excavation in the entrance channel of Panama Bay by 10 ft. The proposition to raise the bottom of the excavation in Culebra Cut 3 ft. to Elevation + 50, instead of retaining it at Elevation + 47, recommended by the Commission, would trench seriously upon the capacity of the canal for ships of the greatest draft. Obviously, it must be recognized that by far the great majority of ships passing through the canal will have considerably less than the maximum draft.

Mr. Burr. At the same time it is also to be remembered that the purpose of this canal construction, as expressed in the language of the law on which the instructions to the Commission were based, is to afford accommodation for the greatest ships afloat. It is only reasonable to suppose that this expression meant complete accommodation and not partial accommodation during some seasons of the year or stages of the tide. This restriction in the canal would lead to seasonal restriction of navigation capacity, which, however, might be partially compensated or relieved by the construction of the Alhajuela Reservoir.

The decrease of depth of 10 ft. in the Panama Channel would be a daily restriction of navigation capacity, since the throttling effect of the diminished channel depth would occur at every tide. For one-fourth of the entire time the canal would be shorn of its greatest capacity. Even if it be admitted that the maximum delay of any ship would not be more than 6 hours, there are conditions under which that might be serious. This consideration carries with it greater gravity in that it would affect the largest ships.

These features were considered most carefully by the Commission, but it seems to the speaker that the decision to plan a canal possessing the maximum prescribed capacity was wise and should not be departed from. If the United States Government is to complete a great canal across the Isthmus for the purpose of affording the freest waterway for ships, the accommodations provided should be subject to no throttling or other substantial restriction of a diminished canal depth at its central portion or at either extremity. Such material disadvantages would constitute objections so serious that the demand to relieve them would probably follow closely the opening of the canal.

The practicability of a sea-level canal across the Isthmus of Panama is much more real than has ordinarily been considered, as Mr. Morison shows, and as indicated so clearly in the report of the Isthmian Canal Commission. In the event of such a construction it would undoubtedly be wise to make the canal prism of such area of section as to receive the flood waters of the Chagres modified by the storage resulting from the construction of the Alhajuela Dam. The question of the area of the prism is in reality the greatest single question involved in the sea-level plan, and whether an area of section of even 15 000 sq. ft., mentioned by Mr. Morison, would be sufficient is not yet determined. Further, it is a serious question whether, even with an additional expenditure of $125 000 000 or more, and the greatly extended time required for construction, it would not be the part of real wisdom for the United States Government to undertake at once the sea-level plan, rather than the elevated plan, with its advantages of reduced cost and shortened time.

Mr. Morison. GEORGE S. MORISON, Past-President, Am. Soc. C. E. (by letter).—The question of lift of locks is one on which the writer feels more

doubt than he does about any other point. The addition of the third lock means more gates and more possible risks; it increases the time of passage by the time necessary to pass through the additional lock. The additional risk is not serious, since the destruction of a gate in the Tiger Hill lock would not affect the water in the summit level, and the gate could readily be replaced. Furthermore, by keeping the lifts of the locks practically uniform throughout, the number of spare gates which must be kept on hand for repairs and renewments, would be reduced. The time required by the extra lock does not appear to be of material importance. The time required to pass through the canal will be a matter of convenience of meeting points more than of close calculations of speed. As many vessels as possible will meet in Lake Bohio, and under any plan it will take longer to pass from Panama Bay to Lake Bohio than from Colon Harbor to Lake Bohio. Mr. Morison.

The total distance from the shore end of the enlargement for Colon Harbor to the shore end of the wide channel through the mud flats in Panama Bay is 41 or 42 miles. This is divided into two canals by a lake more than 12 miles long in the middle; 13 or 14 miles of canal navigation, not including locks, lie between Colon Harbor and the lake; a little more than 14 miles of canal navigation, not including locks, lie between Panama Bay and the lake. It is the navigation of these two canal sections which will regulate the passage across the Isthmus. While the speed of steamers through the canal will vary with their size, the time which a ship of mean dimensions would take to pass through these two sections may be estimated as follows, the speed in the canal being taken at five miles per hour:

Colon Harbor to Tiger Hill lock, 7.28 miles..	1 hour	27 minutes
Tiger Hill lock.....		45 "
Tiger Hill lock to Bohio locks, 5.73 miles...	1 "	9 "
Bohio double locks.....	1 "	15 "
	4 hours	36 minutes

Panama Bay to Miraflores lock, 4.15 miles..		50 minutes
Miraflores lock.....		45 "
Miraflores lock to Pedro Miguel locks, 1.34 miles		16 "
Pedro Miguel double locks.....	1 hour	15 "
Pedro Miguel locks to Lake Bohio, 8.84 miles.	1 "	46 "
	4 hours	52 minutes

This time could be reduced for smaller vessels; it will be exceeded by the largest vessels. It may be said, in a general way, that the time required to pass from either ocean into the interior lake will not be less than four hours, and it should not exceed five hours, except

Mr. Morison. for the very largest class of ships. To these figures should be added the time required to pass through the lake and the time lost in Colon Harbor or Panama Bay. It would, perhaps, be fair to add an hour for each of these terminals, and 1½ hours for the passage of the lake; this would make the total time required for the passage of the canal from 10.5 to 12.5 hours.

Many steamers would take coal at Colon, and all would have to stop at the entrance port to pay tolls, take pilots, etc. There would be abundant room to tie up vessels in the broad harbor section at the Colon end. There is abundant anchorage in Panama Bay, the distance from the canal entrance to this anchorage being determined by the size of the ship and other considerations. There is ample room for ships to anchor in Lake Bohio, where they could get fresh water, and, if necessary, make slight repairs. It is not probable that either section of canal would be traversed by night, except by the smallest class of vessels and in emergencies. Ships would prefer to enter the canal from either end about daylight or soon after noon. Ships entering in the morning would make a daylight passage, meeting in Lake Bohio. Ships entering after noon would spend the night in Lake Bohio and pass out on the following morning, proceeding under despatch orders and meeting the inbound ships at the locks. The Tiger Hill lock will be approximately half way between Colon and Lake Bohio, and the Pedro Miguel locks are approached in about the same length of time from the lake and from Panama Bay.

The intermediate level would reduce the seepage head between the lake and the level below the dam one-third, and increase the distance through which seepage must pass between the lake and the lower level of the Chagres at least three times. The estimated seepage would therefore be reduced one-third. The writer, however, considers that this question of seepage was covered in the discussion of the previous paper,* and does not believe that this reduction would be of sufficient advantage to have any important bearing on the main question. The saving of distance by the use of the Tiger Hill line is also of little value, but the saving of curvature is more important. The great advantage of this location, however, is that it keeps away from the low valley of the Chagres at places where the exposure is greatest. A small map has been prepared showing in detail the present course of the Chagres, and the two swamps through which the overflow of the spillway must be taken if the old location is followed, and indicating the land which is less than 10 m., or 33 ft., above tide level.† Below the dam the Chagres no longer follows its old bed, but for five miles runs through the canal, its old crooked course having been silted up, and from this five miles it must be excluded if the French location is

* "The Bohio Dam." *Transactions*, Am. Soc. C. E., Vol. XLVIII, p. 235.

†This map not received in time for reproduction here; it will appear with this discussion when printed in Vol. L of *Transactions*.

adopted. If the lower location is adopted a channel must be cut through the ridge between the two swamps, and the canal must be protected by levees for at least five miles. This is undoubtedly practicable and can be made safe, but safety is always a measure of degree. The levees built for this purpose, which would be exposed to the wash of a flooded river, would be a more serious matter than the risk to the small embankments required to sustain the canal on the Tiger Hill location. The latter embankments would be exposed to no such wash, and the spoil from the canal would be enough to make them several hundred feet thick. Furthermore, the indications are that it would cost less to build the Tiger Hill line at tide level to the Bohio Locks than to complete and protect a canal on the original location. The writer, however, favors the intermediate lock. Mr. Morison.

The proposition to raise the bottom of the canal through the Culebra Cut 3 ft., as described in the paper, would not necessarily affect the use of the canal for ships of the greatest draft. The depth of 35 ft. was selected to allow ships drawing 32 ft. to pass easily through it. If the precedent of the Manchester Ship Canal is followed, ships drawing 32 ft. could always be handled, although it would be hard to steer them. The writer, however, did not propose to reduce the depth through this summit level, but suggested that there were other methods of maintaining it, besides increasing the depth of this cut. The cost of the Alhajuela Dam will differ but little from the cost of this 3-ft. additional excavation, and will provide a much greater supply of water. If the construction of this dam is postponed until the completion of the canal, the cost of building a railroad to the dam site will be saved, as it can then be reached by water, and other economies, which attend the postponement of work until the rush is over, can be realized. It is not improbable that all the necessary water can be stored by the use of flash-boards, one of the cheapest devices ever made.

The principal objections raised to reducing the depth on the Pacific level relate to military rather than commercial conditions. It must be remembered, however, that the largest merchantmen of to-day are twice as big as the largest naval vessels, and that there are practically no naval vessels which draw over 30 ft. Furthermore, no fleet consists entirely of the heaviest class of ships, but every fleet contains a number of comparatively light-draft boats, used for despatch service and other purposes. If we assume that an entire fleet is taken through the canal at once, a very improbable supposition, the heavy-draft fighting ships will either precede or follow the light-draft ships, according as they expect to encounter a hostile fleet in front of or behind them. It would take approximately an hour to pass from deep water in Panama Bay to the Miraflores Lock. Assuming six hours as the length of time from mean tide to mean tide,

Mr. Morison. this would leave five hours for the passage of the locks, which, allowing half an hour for each passage, special preparations being made, and using both locks, would enable 20-ft. deep-draft fighting ships to pass from Panama Bay into the canal on a single tide. It is not probable that any such number of deep-draft ships will ever be concentrated in a single fleet.

It is the writer's opinion that the advantages offered by Lake Bohio as an interior lake which divides the transit into two short canals more than make up for the delays and limitations of the locks. The strongest argument in favor of the tide-level canal is the vulnerability of the locks. In time of war the canal might be closed entirely by a small guerrilla force. An accident, by which a heavy steamer carried away the gates of a lock, occurring near the beginning of the dry season, might lead to the depletion of water in the lake to such an extent that navigation by deep-draft vessels would be impeded for several months. No such accident could occur to the single tide lock required for the tide-level canal. The danger from malicious destruction may be neglected, as the same harm could be done in various ways, although not as easily, in a tide-level canal. The gate must be kept safe by constant care, and undoubtedly some device can be made by which the discharge through the locks, when the gates are broken, can be stopped. Although the writer would prefer a tide-level canal when completed, he believes that it would be a serious mistake to undertake the tide-level plan at once.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

THOMAS CURTIS CLARKE,* Past-President, Am. Soc. C. E.

DIED JUNE 15TH, 1901.

Thomas Curtis Clarke, the youngest son of Samuel Clarke, of Boston, Massachusetts, was born on September 5th, 1827, in Newton, Massachusetts. It is a tradition that his earliest known ancestor, Thomas Clarke, of Plymouth, came over in the *Mayflower*, as Mate. If so, he went back to England in that vessel, for he arrived the next year as passenger in the *Anne* and settled in Plymouth. He was a man of some note, and several of his personal belongings are to be seen among the relics preserved in Forefathers Hall in that town. Mr. Clarke's grandfather, Major Samuel Clarke, of Boston, married Martha, daughter of Obadiah and Martha Curtis, members of a prominent Boston family. Mr. Clarke's father was a man of varied talents, both scientific and artistic, and his mother was a daughter of General William Hull, of Revolutionary fame, and a first cousin of Commodore Isaac Hull, commander of the frigate *Constitution* (Old Ironsides) when she destroyed the English frigate *Guerriere*.

Mr. Clarke had four brothers and one sister, the best known of them being the Reverend James Freeman Clarke, a Unitarian preacher and author, named for his grandfather, the Reverend James Freeman, who married Martha (Curtis), the widow of Major Samuel Clarke. It was from such antecedents that Mr. Clarke inherited the literary and artistic tastes which characterized him, and which were second only to his engineering ability.

Mr. Clarke's early training was given by his grandmother, Mrs. Freeman, with whom he lived while a child. He says of her: "She taught me to read and to speak the truth." She may also have taught him his characteristic modesty and self-effacement. From 1841 to 1844 Mr. Clarke fitted for College at the Boston Latin School, under the famous Master, Francis Gardner. In the latter year he entered Harvard, and was graduated in the summer of 1848, on which occasion he officiated as class poet.

Mr. Clarke had intended to study the Law; but, being in delicate health at that time, he decided to adopt the profession of Civil Engineering. He obtained a position in the Engineering Corps of the Mobile and Ohio Railway, under Captain John Childe, the foremost

* Committee appointed by the Board of Direction to prepare this memoir: John F. O'Rourke, Adolphus Bonzano and Eliot C. Clarke.

railroad engineer of the day. Here he learned the practical work of railroad location, and here he remained until June, 1849, when a severe attack of fever compelled him to return to Boston. During that fall, while waiting for another position, he studied architecture, in the office of E. C. Cabot, of Boston, gaining knowledge of that profession, and of mechanical drawing, that was of service to him later. At that time there were no schools of engineering, and young engineers had to obtain their technical education as best they could.

Early in 1850 he secured a position as draughtsman under Mr. Shanly, Resident Engineer of the Ogdensburg and Lake Champlain Railway. When the work with which he was connected was completed, he returned to the Mobile and Ohio Railway, and took charge of one of the parties locating that road. This work lasted until September, 1851, when Mr. Clarke went to St. Louis and afterward to Chicago, in which city his mother and two of his brothers were then living. While in Chicago he studied in the office of Edward Burling, an eminent architect of that city. At this time, at the request of William B. Ogden, a public-spirited citizen, Mr. Clarke made a design for a tunnel under the Chicago River.

In October, 1852, he accepted a position under Mr. Benedict, Chief Engineer of the Great Western Railway of Canada, as Resident Engineer of the Second Division, which extended from St. Catherines to Dundas and included much heavy work and the shops at Hamilton. His assistants were Amory Dexter, of Boston; Thomas Ridout, of Toronto, and Augustus Bacon, from the Ogdensburg and Lake Champlain Railway. It was here that Mr. Clarke gained his first experience in foundation work in which he was so successful afterward. After the completion and opening of the road, in 1853, Mr. Clarke went to Port Hope, Ontario, Canada, as Assistant Engineer, under Mr. Benedict, of the Port Hope and Peterboro Railway. This road was finished in 1856, when Mr. Clarke and Mr. George Tate, one of the engineers of the Grand Trunk Railway, took a lease of it and operated it as a private enterprise. In 1858 the directors of the railway broke their contract and took the road from Messrs. Clarke and Tate, who recovered damages after a suit lasting about a year.

In November, 1858, Mr. Clarke was put in charge of one of the three divisions of the Government Survey of the Ottawa River, his work covering French River, Lake Nipissing and the Mattawan. His experiences in the field during the severe Canadian winter were most interesting, and his work was done so well and so promptly that he was placed in charge of the entire survey. The thoroughness of his work is shown by the fact that twenty-five years later, when the Canadian Government improved the Ottawa River, they adopted Mr. Clarke's plans and his exact location for a lock and dams at Carillon, at the head of the Lake of Two Mountains.

In the fall of 1869, Mr. Clarke, in partnership with Ralph Jones and Edward Haycock, took a contract for building the two Government Departmental buildings at Ottawa. Among other materials needed were iron beams, and to purchase these Mr. Clarke visited England in March, 1860. There he made the acquaintance of many distinguished men; among others, William Fairbairn. He was abroad about two months, returning to Quebec on an Allan Line steamship. Sir Hugh Allan had been urged to start his ships from Galway instead of Mobile, in North Ireland, and he sent one of them to try the harbor. It was on her that Mr. Clarke sailed, and he thus was one of the few who ever sailed from that port, as the one trip demonstrated its unsuitableness. The Ottawa buildings were finished in 1866.

About the end of the same year Mr. Clarke was engaged to build a bridge over the Mississippi River at Quincy, Illinois, for the Chicago, Burlington and Quincy Railway. This was the first iron bridge built across that river, and the securing of stable foundations presented many difficulties. The entire bridge was completed in two years without employing any contractors except for furnishing the iron superstructure. This was removed later and a heavier one substituted, on account of the great increase in modern trainloads; but no change was needed in the old piers.

In the fall of 1868 Mr. Clarke moved to New York City, where he formed a partnership with Charles Kellogg for furnishing and building iron structures, under the name of the Phœnix Bridge Company. In the spring of 1870 he moved to Philadelphia, and formed a new firm under the name of Clarke, Reeves and Company. Mr. Clarke was the senior partner, and his associates were Samuel Reeves, John Griffen and Adolphus Bonzano, of Phœnixville, Pennsylvania. The firm of Clarke, Reeves and Company was one of the leading bridge builders of the United States, and, among other works, constructed the Girard Avenue Bridge, over the Schuylkill at Philadelphia, many railroad bridges in the United States and in Canada, the Kinzua Viaduct on the Erie Railway, and a large part of the Elevated Railway system in New York City.

Mr. Clarke severed his connection with this concern in 1883, and in the next year became one of the original members of the Union Bridge Company, with offices in New York. During his connection with this concern, it built the Hawksbury Bridge in Australia, (the contract for it being taken in competition with the whole world), and the Poughkeepsie Bridge over the Hudson River. In building both these bridges the foundation work was very difficult, and Mr. Clarke's great experience in such matters stood him in good stead.

Mr. Clarke retired from the Union Bridge Company late in 1887, and during the remainder of his life carried on a business as Consult-

ing Engineer. He also traveled much, and was prominent among the members of this Society when they visited Europe in 1889. He was consulted by Henry M. Whitney, of Boston, in regard to the elevated railways in that city, and also in connection with mining development work in Nova Scotia. He was Consulting Engineer for the City of New York in building the Third Avenue and the Willis Avenue Bridges, being responsible for the design and construction of them. These were his last works, and he died on June 15th, 1901, in New York City, after a brief illness.

Mr. Clarke was elected a Member of the American Society of Civil Engineers on March 18th, 1868, and a Fellow on May 20th, 1872. He served as a member of the Board of Direction for the year beginning November, 1878, and as Vice-President from November 2d, 1870, to November 1st, 1871. From January 15th, 1896, to January 20th, 1897, Mr. Clarke was President of the Society. He was a Member of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and of the American Philosophical Society of Philadelphia. He was one of the first of the American members of the British Institution of Civil Engineers, and the only American engineer who ever received both the Telford Medal and Premium, they being awarded to him for a paper, written in 1878, on "The Design Generally of Iron Bridges of very Large Span for Railway Traffic."

Notwithstanding his modesty and retiring disposition, Mr. Clarke was very popular. He was a member of many clubs and associations in different parts of the country, and in New York City was a member of the Union, Century, Harvard, Manhattan, St. Andrew's Golf and other clubs. He contributed many professional papers to the various engineering societies to which he belonged. He wrote the article on "Engineering" for "The Progress of the Century," published in 1900, to which men eminent in other branches of knowledge also contributed articles.

In the *Minutes of Proceedings* of the British Institution of Civil Engineers, Sir Benjamin Baker writes thus:

"The death of my old friend Mr. Clarke will be sincerely lamented by many British engineers, for no one has done more than he to promote the cordial brotherly relationship which now happily exists between American and British engineers. It also severs one more link with the past, for Mr. Clarke's early experience with bridge building was in the days when there was hardly one point of resemblance between American and British wrought-iron bridges, the former being modeled after the type of the original timber-truss construction and the latter on that of the cast-iron shallow-girder system. Mr. Clarke sometimes said that he shuddered when he thought of some of his early bridges, with long, slender cast-iron posts, slight lateral bracing, and totally inadequate pin-connections, even the floor girders being of the latter type, instead of the heavily-riveted low-stressed type which he lived to see substituted in all American bridge-work, as he

also saw each country gradually introduce the good points of the other's practice, so that no vital difference now distinguishes European and American bridges."

Mr. Clarke's life and works illustrate the highest form of engineering ability, while his modesty and straightforward, lovable character won for him hosts of friends. His death removed one of the brilliant lights of the engineering profession.

WILLIAM DURFEE GELETTE, M. Am. Soc. C. E.*

DIED APRIL 27TH, 1902.

William Durfee Gelette was born in Fairhaven, Massachusetts, on March 1st, 1847, and received his education at the Massachusetts Institute of Technology, being a member of the Class of 1869.

After leaving college he was employed until 1875 on various engineering works in New England, including water supply, drainage, iron bridge construction and street improvements, under such masters as Clemens Herschel and J. Herbert Shedd.

In 1875 Mr. Gelette went to California and entered the employ of the Southern Pacific Railroad Company, with which company and its successors he remained, almost continuously, up to the time of his death. He was in charge of the construction of the Southern Pacific transcontinental line from the Colorado River, on the border of California, to the Pecos River, in Texas, a distance of nearly 1 000 miles. Later, he was in charge of the construction of many other lines for that company, and from 1883 to the time of his death he occupied the second place in the Engineering Department of the road.

Mr. Gelette's life was ideal from the standpoint of an Engineer: Conscientious, hard working, tireless, he took up everything presented to him with the thorough method necessary to achieve the best results. These qualities made him the trusted lieutenant of those he served, and, combined with his sympathy and patience, earned for him the highest regard of his subordinates.

He was married in Boston in 1871, and his married life was a particularly happy one. His nature was domestic, and he enjoyed nothing more than his home and his family. His widow, a son and a daughter survive him.

In the early part of April, 1902, in the interests of his employers, he visited El Paso, Texas, and was taken ill. His conscientious regard for his work kept him at his post until it was complete, after which his strength barely permitted him to make the return trip to his home, in Oakland, California, where he quietly passed away a few days later.

* Memoir prepared by W. B. Storey, M. Am. Soc. C. E.

He was elected a Member of the American Society of Civil Engineers on April 1st, 1885, and always took the greatest interest in its work.

JOSEPH MILLER WILSON,* M. Am. Soc. C. E.

DIED NOVEMBER 24TH, 1902.

Joseph Miller Wilson was born at Phœnixville, Chester County, Pennsylvania, on June 20th, 1838. He was a son of William Hasell and Jane Miller Wilson. His father and his grandfather were well-known civil engineers in the United States, his father being an Honorary Member of the American Society of Civil Engineers, and for many years Chief Engineer of the Pennsylvania Railroad. Mr. Wilson's great-grandfather and great-great-grandfather were among the most prominent civil engineers of their time in Scotland.

After a thorough preparation in private schools, Mr. Wilson entered the Rensselaer Polytechnic Institute, of Troy, New York, and was graduated therefrom in 1858, with the degree of Civil Engineer; after which he took a two years' special course in analytical chemistry with Professor F. A. Genth, of Philadelphia.

In 1860 Mr. Wilson entered the service of the Pennsylvania Railroad as Assistant Engineer, and in 1863 became Resident Engineer of the Middle Division. In 1865 he became Principal Assistant Engineer, and, later, Engineer of Bridges and Buildings of the Pennsylvania Railroad, continuing in the service of this road until January 1st, 1886.

Among the various structures designed and built by Mr. Wilson during this period were the Susquehanna and Schuykill Bridges, the original Broad Street Station, the Baltimore and Potomac Station at Washington, the Main Exhibition Building and Machinery Hall of the Centennial Exhibition, and, later, the Drexel Building and the Drexel Institute.

In 1876 Mr. Wilson, with his brothers, organized the firm of Wilson Brothers and Company, Civil Engineers and Architects, and this firm has done a very large amount of detail and expert work. The bridges designed and erected by him comprise all those on the Pennsylvania Railroad for many years, and many on other roads, the number too great to mention in detail. His firm were engineers and architects for numerous stations, shops, etc., on various railroads: Shops of the Northern Central Railroad at Baltimore; the Alleghany Valley Railroad shops at Verona, Pennsylvania; stations and shops for the Ninth and Third Avenue lines of the New York Elevated Railroad; stations and shops for the New York, West Shore and Buffalo Railroad; and stations on the Lehigh Valley, New Jersey Central, and Philadelphia and Reading Railroads.

* Memoir prepared by Joseph M. Knap, M. Am. Soc. C. E.

Mr. Wilson was Chairman of the Board of Expert Engineers on the Washington Aqueduct Tunnel and Reservoir, acting under a joint Commission of Congress, in 1888-89; was Chairman of the Board of Expert Engineers to examine and report on the railroad terminal and station question at Providence, Rhode Island, in 1888; was one of the expert engineers to make examinations and report on the condition of the elevated railroads in New York City. He was one of the experts on the designs for the approaches of the New York and Brooklyn Suspension Bridge, and also one of the expert engineers reporting to the Board of Rapid Transit Commissioners for the City of New York, in 1891. In more recent years he was the Consulting Engineer for the Philadelphia and Reading Railway Company, and had charge, for that company, of all work on the Pennsylvania Avenue Subway, in the City of Philadelphia. He was one of the engineers appointed to examine and report on the improvement of the water supply for the City of Philadelphia, in 1899, the work being now carried out in accordance with that report.

Mr. Wilson wrote many scientific and engineering papers, among them the "Mechanical," the "Scientific," and the "Historical" for the "Illustrated Catalogue of the International Exhibition of 1876." He also wrote historical papers on this exhibition for London *Engineering*. By special request, he wrote a paper, on "American Permanent Way," for the British Association. He also wrote a comprehensive paper,* "On Specifications for Strength of Iron Bridges," and a paper† entitled "The Philadelphia and Reading Terminal Railroad and Station in Philadelphia," for the American Society of Civil Engineers; a paper on Port Perry Bridge, for the Institution of Civil Engineers; and a paper‡ on "Schools," with particular reference to Trade Schools, especially those of France and England. He also wrote sundry papers for various scientific and engineering journals.

As an inventor, Mr. Wilson took out several patents: On bridge details, flushing tanks for sanitary purposes, etc., etc.

He held many positions of honor and responsibility, some of them being as follows: Member of the American Society of Civil Engineers; Member of the Institution of Civil Engineers; Fellow of the American Institute of Architects; Member of the Franklin Institute, of which he was Manager from 1868 to 1887, and President for ten years, 1887 to 1897; President of the Engineers' Club of Philadelphia for 1888; Member of the American Philosophical Society; Fellow of the American Association for the Advancement of Science; Member of the Century Association of New York City.

Mr. Wilson received the honorary degree of Master of Arts from the University of Pennsylvania in 1877. At the Centennial Exhibition

* *Transactions*, Am. Soc. C. E., Vol. XV, pp. 389, 484; Vol. XVI, p. 38.
† *Transactions*, Am. Soc. C. E., Vol. XXXIV, p. 115.
‡ *Journal*, Franklin Institute, 1889-90.

of 1876, in Philadelphia, he received medals and awards for designs of bridges and buildings, and in 1878 he received the Telford Premium from the Institution of Civil Engineers.

He was married to Miss Sarah Pettit, daughter of Judge Thomas McKean Pettit, on May 24th, 1869. They had two children, Alice May and Mary Hasell Wilson.

Mr. Wilson died of heart disease, suddenly, in his office in Philadelphia, on November 24th, 1902, in his sixty-fifth year. He is survived by his wife and his daughter, Mrs. John T. Gibson, of New York City.

For some years Mr. Wilson was a member and vestryman of St. Stephens Church, in Philadelphia. In the words of a resolution passed by this vestry:

"Mr. Wilson was a man in whom the power and the beauty of the Christian religion conspicuously manifested themselves. * * * Confronted constantly with difficult problems, he knew no other standard of conduct than the example of Jesus and his own very delicate sense of honor. Just in all his relations, generous to a fault, truthful in word, pure in spirit, a loving husband, father, brother, and son—these moral virtues only added luster to the endowment of a naturally powerful mind, nor did his religious beliefs prove inimical to scientific attainments which placed him at the head of an exacting profession."

The foregoing gives but an outline of a very useful, honorable and well-rounded life. His was an exemplification of what great results a quiet, unostentatious, industrious life can accomplish in the scientific and industrial world, when accompanied by superior intelligence, a thorough education and a morality based upon strict religious principles.

The writer of this memoir would feel that he had not done the subject justice had he not, in closing, alluded briefly to the high moral purpose which actuated Mr. Wilson in all that he did; and to the religious faith and practice, which, from his early youth until the day of his death, were the controlling influences of his successful and happy life.

Mr. Wilson was elected a Member of the American Society of Civil Engineers on April 2d, 1873. He served as a Director from January 18th, 1888, to January 16th, 1889; and as Vice-President from January 17th, 1894, to January 15th, 1896.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 5.

MAY, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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NEW YORK 1903.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS in the office of the Librarian of Congress, at Washington.

American Society of Civil Engineers.

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President, ALFRED NOBLE.

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Term expires January, 1904:	*Term expires January, 1905:*
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JOHN R. FREEMAN.	JAMES D. SCHUYLER.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1904:	*Term expires January, 1905:*	*Term expires January, 1906:*
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GEORGE F. SWAIN,	GEORGE H. PEGRAM,	JOSEPH O. OSGOOD,
EMIL KUICHLING,	WILLIAM J. WILGUS,	GEORGE S. DAVISON
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EDWARD C. CARTER,	EDMUND F. VAN HOESEN,	HUNTER McDONALD
FRANK C. OSBORN.	JAMES L. FRAZIER.	ELWOOD MEAD.

Assistant Secretary, T. J. McMINN.

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THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

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L. F. G. BOUSCAREN,	ALFRED CRAVEN,	MORDECAI T. ENDICOTT,
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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 533 Columbus.
CABLE ADDRESS, - - - "Ceas, New York."

Vol. XXIX. MAY, 1903. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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May 6th, 1903.—The meeting was called to order at 8.55 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 123 members and 13 guests.

The minutes of the meetings of April 1st and 15th, 1903, were approved as printed in *Proceedings* for April, 1903.

A paper entitled "A Small Rock-Fill Dam," by H. de B. Parsons, M. Am. Soc. C. E., was presented by the author and illustrated with lantern slides. The Secretary presented a written communication from Samuel H. Lea, M. Am. Soc. C. E., and the subject was discussed further by Messrs. Foster Crowell, J. M. Goodell and the author.

A second paper, entitled "Deflections of Beams with Variable Moments of Inertia," by C. W. Hudson, M. Am. Soc. C. E., and a written communication from Irving P. Church, Assoc. Am. Soc. C. E., were presented by title, and the subject was discussed further by Mansfield Merriman, M. Am. Soc. C. E.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Frank Lloyd Averill, Washington, D. C.
Bernard Bienenfeld, San Francisco, Cal.
Thomas Avery Corry, Puebla, Mexico.
Carlton Rollin Dart, Chicago, Ill.
Ernest Howard Foster, New York City.
Kenneth Phipson Hawksley, London, England.
William Ross Hillyer, West New Brighton, N. Y.
Ernest McCulloh, Seattle, Wash.
Archibald McLean, Brooklyn, N. Y.
Ashbel Edward Olmsted, New York City.
Isaac Rich, Boston, Mass.
Edward Whitten Shedd, Providence, R. I.
Joseph Emory Sirrine, Greenville, S. C.
David Heikes Whitmer, Charleston, S. C.

As Associate Members.

Astolfo Bartoccini, New York City.
Charles Blaney Breed, Lynn, Mass.
Charles John Eld, Jr., St. Joseph, Mo.
James Welch Frazier, Cleveland, Ohio.
Charles Gartensteig, New York City.
Robert Ladd Gifford, Chicago, Ill.
Isaac Harby, Trenton, N. J.
Frederick Lawrence Hartigan, Chicago, Ill.
Don Hays, Kansas City, Mo.
Hermann Meriwether Knapp, Pencoyd, Pa.
Moses Jerome Look, Clinton, Mass.
Frank Howard Neff, Cleveland, Ohio.
Charles Edward Parsons, Glens Falls, N. Y.
Howard Platt Treadway, Kansas City, Mo.
Earnest Maitland Van Norden, Brooklyn, N. Y.
Hans von Unwerth, Kansas City, Mo.

The Secretary announced the election of the following candidates by the Board of Direction on May 5th, 1903:

As Associate.

Charles Henry Umstead, Portsmouth, N. H.

As Juniors.

Arthur Herbert Diamant, New York City.
Charles Louis Fox, Wilkinsburg, Pa.
Louis Adams Robb, Newark, N. J.
Charles Rapelyea Wyckoff, Jr., Brooklyn, N. Y.

The Secretary announced the following deaths:

Walter S. Gurnee, elected Fellow May 10th, 1870; died April 17th, 1903.

Edward Appleton Greene, elected Member July 4th, 1888; died April 19th, 1903.

Victor M. Clement, elected Fellow January 8th, 1890; died April 28th, 1903.

Adjourned.

May 20th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 76 members and 7 guests.

A paper entitled "The Economic Improvement of the Coosa and Alabama Rivers, in Georgia and Alabama," by D. M. Andrews, M. Am. Soc. C. E., was presented by the Secretary, who also read a communication on the subject from Capt. R. R. Raymond, Corps of Engineers, U. S. A.

The Secretary announced the death of the following members:

George Richardson Hardy, elected Member November 7th, 1888; died April 2d, 1903.

Edmund Dorman Libby, elected Member May 6th, 1885; died April 24th, 1903.

William George McNeill Thompson, elected Member July 2d, 1879; died May 12th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

May 5th, 1903.—8.30 P. M.—President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Croes, Jackson, Knap, Osborn, Osgood, Pegram and Schneider.

A special report was presented from a Committee appointed to consider the advisability of the discontinuance of advertisements in *Proceedings*, and the Secretary was instructed to discontinue all advertisements in the *Proceedings* of the Society, as soon as it can be done under existing contracts.

Applications were considered and other routine business transacted.

One candidate for admission as Associate, and four as Junior were elected.*

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, June 3d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by Richard T. Dana, Assoc. M. Am. Soc. C. E., entitled "A New Safety Explosive," will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, September 2d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "An Experimental Study of the Resistances to the Flow of Water in Pipes," by Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E., will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, September 16th, 1903.—8.30 P. M.—At this meeting a paper, by Elmo G. Harris, M. Am. Soc. C. E., entitled "Theory of Centrifugal Pumps and Fans: Analysis of their Action, with Suggestions for Designs," will be presented for discussion. This paper is printed in this number of *Proceedings*.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches for members to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and, whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

PROPOSED AMENDMENT TO THE CONSTITUTION.

The following proposed amendment to the Constitution has been received by the Secretary, and has been sent to all Corporate Members of the Society. In accordance with the provisions of Section 3 of Article IX of the Constitution, it will be considered at the Business Meeting of the Annual Convention at Asheville, N. C.

Amend the Constitution by striking out Sections 6, 7 and 8 of Article II, and the whole of Article III, and substituting therefor the following:

ARTICLE II.—Membership.

* * * * * * * *

6.—A Junior shall not be less than eighteen years of age, and his connection with the Society shall cease when he becomes thirty years of age, unless he be previously transferred to another grade. He shall have had active practice in some branch of engineering for at least two years, or he shall have graduated from a school of engineering of recognized standing. Persons who are in the Junior class at the time of the adoption of this Constitution shall not have their status changed by the provisions of this section.

7.—Honorary Members shall be chosen only from persons of acknowledged eminence in some branch of engineering or the sciences related thereto. There shall not be more than twenty at any one time.

8.—Fellows shall be contributors to the permanent funds of the Society, though they may not be eligible for admission as Corporate Members.

ARTICLE III.—Admissions and Expulsions.

1.—Honorary Members shall be proposed by at least ten members, and shall be elected only by a unanimous vote of the Board of Direction. A Past-President, or a member of the Board of Direction proposed for Honorary Membership, shall not be required to vote either for or against his own admission.

A person elected an Honorary Member shall be promptly notified thereof by letter. The election shall be cancelled if an acceptance is not received within six months after the mailing of such notice.

2.—An application for admission to the Society or for transfer from one grade to another shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected. The applicant shall furnish the names of at least five Corporate Members to whom he is personally known. Each of these shall be requested by the Secretary to address a letter to the Board of Direction, on a form prescribed by said Board, stating the extent of the writer's personal knowledge of the applicant and of his professional work. If at least five of the Corporate Members named as references do not furnish the requisite endorsement, the Secretary shall call upon the applicant for additional names, and not until written communications shall have been received from at least five Corporate Members shall the application be considered by the Board.

Applications of engineers not resident in North America, and who may be so situated as not to be personally known to five Corporate Members, may be recommended for ballot by five members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

3.—At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for admission or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on applications for admission may direct a ballot.

The Board shall have the power to transfer persons from a lower to a higher grade of membership, and shall notify the membership of its action.

4.—The ballots shall be letter-ballots, in a form to be prescribed by the Board of Direction. They shall be mailed to each Corporate Member whose address is known, and shall state the date on which the ballot is to be canvassed, which shall be not less than twenty days after the issue of the ballot. Twenty or more negative votes shall exclude from election. In case of ex-

clusion, no notice thereof shall be entered on the minutes, but the candidate shall be notified.

5.—All elected candidates shall be duly notified and shall subscribe to the Constitution and Rules of the Society. Forms for these purposes shall be prescribed by the Board of Direction. If these provisions are not complied with within six months from the notification of election, such election shall be considered void, unless for special reason the time shall be extended by the Board of Direction.

Membership of any person shall date from the day of his election.

6.—Upon the written request of ten or more Corporate Members, that for cause therein set forth a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He may, if he so desires, present a written defence which shall be considered at a meeting of the Board of Direction, of which he shall receive due notice. Not less than two months after such meeting, the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a defence made which is satisfactory to the Board, it shall then notify the person that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Corporate Members by letter-ballot in a form to be prescribed by the Board of Direction. The ballot shall be accompanied by a statement of the charges, and of the action of the Board thereon, with such information as it deems proper, and also the statement of the person making the appeal. The ballot shall be canvassed by the Board not less than twenty days after its issue. A majority of the ballots cast will be required to sustain the action of the Board. The Board will notify the person and the Corporate Members of the result of the ballot. In case no appeal be made, the Board of Direction will expel the person, and notify him and the Corporate Members of its action.

7.—A member of any grade in the Society may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Direction; when, if all his dues have been paid, his resignation shall be accepted.

8.—All persons elected and duly qualified, whose address on the records of the Society is within fifty miles of the Post Office in the City of New York, shall be deemed Resident; and those whose address is beyond that limit shall be deemed Non-Resident.

The classification of each person for the fiscal year as Resident or Non-Resident, shall be determined by the Records of the Society as they may appear on January 1st of that year.

The foregoing amendment is proposed by the following Corporate Members:

John F. Wallace,	Geo. S. Davison,
David Sloan,	Emil Swensson,
Ralph Modjeski,	J. A. Atwood,
J. W. Schaub,	W. C. Hawley,
Albert F. Reichmann,	W. G. Wilkins,
C. A. Hasbrouck,	Josiah A. Briggs,
Frank J. Llewellyn,	J. J. R. Croes,
Charles L. Strobel,	A. Noble,
Geo. F. Swain,	H. S. Haines,
William Jackson,	Jos. O. Osgood,
John E. Cheney,	Geo. H. Pegram,
S. Everett Tinkham,	Edw. P. North.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention will be held at Asheville, N. C., June 9th, 10th, 11th and 12th, 1903.

The arrangements for the Convention are in the hands of the following Committees:

Committee of the Board of Direction.

J. James R. Croes, *Chairman.*

George H. Pegram, Chas. Warren Hunt.

Local Committee.

J. L. Ludlow, *Chairman.*

William Cain,	W. A. Leland,
Wilbur F. Foster,	J. Imbrie Miller,
George W. Frank,	J. A. Montgomery,
J. C. Guild,	E. T. D. Myers,
J. N. Hazlehurst,	Arthur Pew,
W. B. W. Howe,	George O. Tenney,

Nisbet Wingfield.

The following programme has been arranged:

Tuesday, June 9th, 2.00 P.M. Opening Session.—Address of Welcome by the Hon. Theodore F. Davidson.

Business Meeting: The question as to the time and place for holding the next Annual Convention will be discussed, and a proposed amendment to the Constitution will be taken up in regular course. It is also probable that there will be an infor-

mal consideration of the proposed co-operation of the Society with the other National Societies and the Engineer's Club of New York, in the matter of a Joint Engineering Building.

8.30 P. M. Second Session.—Annual address, by Alfred Noble, President, Am. Soc. C. E.

Wednesday, June 10th, 10.00 A. M. Third Session.—Professional Discussion on Topics Nos. 1, 2 and 3.

Afternoon.—An Excursion by trolley around Asheville and a visit to the Swannanoa Country Club has been arranged for this afternoon.

9.00 P. M.—Reception.—The Hon. Charles B. Aycock, Governor of North Carolina, has accepted the invitation of the Local Committee to meet the members and guests of the Society this evening.

Thursday, June 11th, 10.00 A. M. Fourth Session.—Professional Discussion on Topics Nos. 4, 5 and 6.

3.00 P. M.—Excursion to Sunset Mountain. By invitation of Richard S. Howland, Esq., President, Asheville and Craggy Mountain Railroad Company, the Society will visit Overlook Park, on Sunset Mountain, spending the afternoon and remaining there until after sunset. R. H. Tingley, M. Am. Soc. C. E., will be with the party, and will describe the interesting features of the construction of this road at the Pavilion, on arrival at the Park.

At 5 P. M. the party is invited to a Barbecue by Mr. Howland, and the return to the Hotel will be made about 9 P. M.

Evening.—Concert.

Friday, June 12th, 10.00 A. M. Fifth Session.—Adjourned Business or Professional Meeting, if necessary; otherwise the morning will be free for individual trips to points of interest in the vicinity.

1.30 P. M.—A drive through "Biltmore," the estate of George W. Vanderbilt, Esq., has been arranged for this afternoon.

9.00 P. M.—Informal dancing in the ballroom of the Battery Park Hotel.

TOPICS FOR INFORMAL DISCUSSION.

Topic No. 1. Timber Tests.

This discussion will be opened by representatives of the U. S. Bureau of Forestry (see *Proceedings* for April, 1903, p. 133).

Topic No. 2. Sewage Purification.

Rudolph Hering, M. Am. Soc. C. E., will introduce this subject.

Topic No. 3. In the treatment of the Mississippi River, is the Levee Theory Justified by Experience?

Discussion on this subject will be introduced by B. M. Harrod, Past-President, Am. Soc. C. E.

Topic No. 4. Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

This discussion will be introduced by William B. Landreth, M. Am. Soc. C. E.

Topic No. 5. What is the effect of Sea-Water upon Steel, and upon Steel and Concrete used in Combination, and is the use of Steel in Sea-Water admissible?

Topic No. 6. In view of the increasing weights of Rolling Stock, for what loadings should Railroad Bridges be designed?

Henry W. Hodge, M. Am. Soc. C. E., will open this discussion.

ACCESSIONS TO THE LIBRARY.

From April 8th to May 12th, 1903.

DONATIONS.*

A MANUAL OF FIELD AND OFFICE METHODS

For the Use of Students in Surveying. By William D. Pence and Milo S. Ketchum. Third Edition. Leather, 7 x 5 ins., 252 pp., illus. New York, Engineering News Publishing Co., 1902. $2.00.

The preface states that in preparing this manual the following points have been kept especially in view: (1) To provide a simple and comprehensive text designed to anticipate and supplement, rather than replace, the usual elaborate treatise. (2) To bring the student into immediate familiarity with approved surveying methods. (3) To cultivate the student's skill in the rare arts of keeping good field notes and making reliable calculations. This third edition is issued to meet the call for the manual at various technical institutions and from practicing engineers. With a view to increase the value of the book, both for teaching and for reference purposes, various revisions and additions have been made. Among these are the full scale samples of field notes on the inset sheet at the back of the book. The Contents are: General Instructions; The Chain and Tape; The Compass; The Level; The Transit; Topographic Surveying; Land Surveying; Railroad Surveying; Errors of Surveying; Methods of Computing; Freehand Lettering.

THE PRINCIPAL SPECIES OF WOOD:

Their Characteristic Properties. By Charles Henry Snow, M. Am. Soc. C. E. Cloth, 10½ x 7 ins., 16 + 203 pp., illus., 39 plates. New York, John Wiley & Sons, 1903. $3.50.

The preface states that this book is a brief, untechnical presentation of the general features characterizing economically important species of wood. It is the result of notes originally brought together from many already existing sources and later augmented, and verified, as far as possible for present use, by personal observation. This work is intended for those who are not foresters or botanists, but who use woods or desire knowledge of their distinguishing properties. Allusion to trees, historical and other references, aside from those directly regarding woods, are made for completeness and in order to mark, distinguish, or separate the species. The book is divided into three parts: Introduction; Broadleaf or Hardwoods; Needleleaf or Softwoods. There is an index of eleven pages.

IRRIGATION INSTITUTIONS.

A Discussion of the Economic and Legal Questions Created by the Growth of Irrigated Agriculture in the West. By Elwood Mead. Cloth, 7½ x 5 ins., 11 + 392 pp., illus. New York, The Macmillan Company, 1903. $1.25. (Donated by the Author.)

The preface states that this work is based on twenty years' experience in the development of irrigated agriculture in the arid West. Fifteen years of this time were devoted to the study and administration of irrigation laws as assistant state engineer of one commonwealth and territorial and state engineer of another. The duties of these positions brought the writer into personal and official relations with all classes of men to whom the problems of irrigation were of vital interest. These included not only farmers, ditch builders, and investigators in irrigation securities, but also legislators and jurists who were shaping the legal principles which are to control the distribution and use of Western water supplies. The Department of Agriculture is studying the methods of distributing and using water in order to promote its more skillful and effective use, and is inquiring into the social and legal questions created by the use of streams in irrigation, both in this country and in other lands. From its beginning the writer has been in charge of these investigations. The convictions expressed have been more largely shaped by what has been seen than by what has been read. The Contents are: Introduction; Land Laws of the Arid Region; The Beginnings of Irrigation; The Doctrine of Appropriation; Contract Water Rights; Measurement of Water; The Duty of Water; Irrigation in Colorado; Irrigation in California; Irrigation in Utah; Irrigation in Wyoming; Irrigation in Other Arid and Semi-arid States; Riparian and Interstate Rights; Methods and Measures Needed for Future Development. There is an index of eight pages.

* Unless otherwise specified, books in this list have been donated by the Publishers.

COMPRESSED AIR INFORMATION;

Or, A Cyclopedia Containing Practical Papers on the Production, Transmission and Use of Compressed Air. Edited by W. L. Saunders, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 1 175 pp., illus. "Compressed Air," New York, copyright 1903. $5.00. (Donated by the Editor.)

This publication has been called for by many inquiries addressed to the editor of *Compressed Air* asking for various papers, some of them original and others compiled, which have been published in that magazine during the first five years of its existence. The supply of the early issues having been long since exhausted and the demand continuing, an effort has been made to present in a single book of reasonable size all the important practical information contained in the first five volumes. No attempt has been made to introduce new matter, but the various papers, editorials and notes have been selected and arranged under suitable headings so that any one seeking information on this subject may be afforded facilities for finding it properly classified. There is an index of seven pages.

SILICO-CALCAREOUS SANDSTONES.

Building Stones from Quartz-Sand and Lime. Chemical and Technical Principles of Their Manufacture According to the Situation, Erection, and Management of Brick Works. By Ernst Stöffler. Paper, 36 pp., illus., 5 plates. N. Y., Spon & Chamberlain. $1.00.

This book describes in detail several processes for making artificial building stone and brick from mixtures of silicious sand and lime; the hardening of the stone being obtained either in the open air or by steam under high or low pressure.

RULES FOR RAILWAY LOCATION AND CONSTRUCTION

Used on the Northern Pacific Railway. By E. H. McHenry, M. Am. Soc. C. E. With an Additional Chapter on Estimating Overhaul in Earthwork, Compiled by H. P. Gillette. Cloth, 8 x 5 ins., 88 pp. New York, The Engineering News Publishing Co., 1903. $1.00.

The Chapter headings are: Construction and Engineering Departments; Location; Surveys and Construction; Track and Ballast; Bridges and Culverts; Accounting and Miscellaneous; Supplies; Estimating Overhaul in Earthwork.

ENGINEERING STUDIES. Parts III, IV and V.

By Charles Evan Fowler, M. Am. Soc. C. E. Paper, 10½ x 7 ins., 3 vol., illus. New York, The Engineering News Publishing Co., 1901–1903. 25 cents per vol.

This is a collection of photographic views of engineering works to which short descriptions and criticisms are appended. Parts I and II have appeared previously. The Contents are: Part III. English Stone Arches; Part IV. French Stone Arches; Part V. German and Austrian Stone Arches.

THE IMPROVEMENT OF RIVERS.

A Treatise on the Methods Employed for Improving Streams for Open Navigation, and for Navigation by Means of Locks and Dams. By B. F. Thomas, M. Am. Soc. C. E., and D. A. Watt, M. Am. Soc. C. E. Cloth, 12 x 9½ ins., 14 + 356 pp., illus., 92 plates. New York, John Wiley & Sons, 1903. $6.00 net; postage 47 cents additional.

The object of this work is to provide in concise form a description of the various systems used in bettering the conditions of navigable streams, together with the methods usually adopted for their design and execution. It has been the endeavor to include all the important points of design and construction which are likely to be met, and all calculations have been simplified so as to bring them within the range of those who are not thoroughly educated, yet whose services are most valuable on river work by reason of their practical experience and good judgment. The authors believe that, as this branch of engineering is virtually untaught in the engineering schools of this country, the advent of this treatise will widen the scope of the usual engineering course and prepare students for entering the engineer service of the Government through the junior engineer grade of the civil service. With this object in view hydrographic surveys and reports and examinations have been treated at some length. The Contents are: Introduction; Characteristics of Rivers; Preliminary Examinations and Surveys;

Topographical Surveys and Leveling; Hydrographic Surveys; Removal of Bars and Other Obstructions; Regularization; Dikes and their Effects; Protection of Banks; Levees; Storage Reservoirs; Improvement of River Outlets; General Design and Construction of Works for Creating Slack Water; Locks; Lock Gates and Valves; Fixed Dams; Movable Dams; Needle Dams; Chanoine Wicket Dams; Gate, Curtain and Bridge Dams; Shutter and A-Frame Dams; Drum Wickets and Bear-Traps; Recent Construction of Movable Dams; Dimensions, etc., of Locks and Dams of Certain Rivers; Specifications; Laws for the Protection and Preservation of the Navigable Waters of the United States. There is an index of six pages.

ELECTRICITY AS APPLIED TO MINING.

By Arnold Lupton, M. Inst. C. E., M. I. Mech. E., M. Inst. E. E.; G. D. Aspinwall Parr, M. Inst. E. E., A. M. I. Mech. E., and Herbert Perkin, M. I. M. E. Cloth, 9 x 6 ins., 7 + 280 pp., illus. New York, D. Van Nostrand Co., 1903. $3.50.

The aim of the authors of this volume has been to present the leading truths and main principles of electricity and electrical engineering without going into great detail, their intention being that, for further information on the theory and practice of the subjects of electrical and mining engineering, recourse should be had to some of the many standard works already in existence. They have been unable, in the space at their disposal, to deal with all the varieties of machines and appliances now in use, typical examples of good practice being considered sufficient for the present purpose. The chapter headings are: Introductory; Dynamic Electricity; Driving of the Dynamo; The Steam Turbine; Distribution of Electrical Energy; Starting and Stopping Electrical Generators and Motors; Electric Cables; Central Electrical Plants; Electricity Applied to Pumping and Hauling; Electricity Applied to Coal-Cutting; Typical Electric Plants Recently Erected; Electric Lighting by Arc and Glow Lamps; Miscellaneous Applications of Electricity; Electricity as Compared with other Modes of Transmitting Power; Dangers of Electricity. There is an index of ten pages.

CONDUCTORS FOR ELECTRICAL DISTRIBUTION;

Their Materials and Manufacture, the Calculation of Circuits, Pole-Line Construction, Underground Workings, and other Uses. By F. A. C. Perrine, M. Am. Inst. E. E. Cloth, 9 x 6 ins., 7 + 287 pp., illus. New York, D. Van Nostrand Co., 1903. $3.50.

The author states in the preface that this book represents the results of over ten years of work as a manufacturer of insulated wires and cables, as an engineer advising concerning their installation and finally as a teacher of electrical engineering. Over eight years has been consumed in actually writing and revising. The original rough cast was published in *Electrical Engineering*, the last chapter appearing three years ago. The author has made a final revision and has presented the whole as a book through the belief that by the previous publication he has been enabled to eliminate from its pages descriptions of materials and methods that are not founded on safe engineering principles. The Contents are: Conductor Materials; Alloyed Conductors; The Manufacture of Wire; Wire-Finishing; Wire Insulation; Cables; Calculation of Circuits; Kelvin's Law of Economy in Conductors; Multiple Arc Distribution; Alternating Current Calculation; Overhead Lines; The Pole Line; Line Insulators; Underground Conductors. There is an index of seven pages.

DIRECTORY OF AMERICAN CEMENT INDUSTRIES AND HAND-BOOK FOR CEMENT USERS.

Edited by Charles Carroll Brown, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 645 pp. Municipal Engineering Company, Indianapolis, 1901. (Donated by the Editor.)

The publication of this Directory is the direct result of the many demands for information upon all questions connected with the manufacture, sale, and use of cement which have been made upon the *Municipal Engineering Magazine*, and of the conclusion drawn that the time has now arrived for the publication of such a book, giving more particularly from the practical and commercial standpoints the answers to all the classes of questions which those interested in cement are asking. The Contents are: Preface; Introduction; Testing of Cement; Specifications for Cement; The Uses of Cement; Specifications for the Use of Cement; Data for Estimates of Cement Work; Cement Laboratories; Freight Rates on Cement; Explanation of Reference Notes; Description of Works and of Processes for the Manufacture of Cement; Directory of Cement Brands; Directory of General Sales Agents; Classified Directory of Cement Dealers and Users; Dealers in Cement; Contractors and Large Users of Cement; Engineers, Architects and Other Supervisors of the Use of Cement; Workers in Cement; Cement Tests and Analyses; Machinery and Supplies for Cement Plants; Dealers in Lime and Plaster; Manufacturers of Lime; Manufacturers of Plaster. There is an index of eight pages.

EXPERIMENTS ON THE FLEXURE OF BEAMS,

Resulting in the Discovery of New Laws of Failure by Buckling. By Albert E. Guy. Cloth, 8 x 6 ins., 122 pp., illus. New York, D. Van Nostrand Company, 1903. $1.25 net.

The preface states that the analogy of the failure of the compression side of a beam by buckling to the method of failure of a long column was, of course, long ago remarked, but it is believed that there has been no previous attempt—certainly no successful attempt—to connect the two by a formula. Mr. Guy's experiments have been successful beyond any reasonable expectation in connecting them and in showing that Euler's formula for long columns is, in fact, the fundamental formula which lies at the base of the whole subject. The Contents are: Introduction; A Simple Problem; The Transverse Shearing; The Longitudinal Shearing; The Deflection of the Beam; Experiments; Corollary; That Simple Problem; The Best Form of Section; The Central Web; The Width of the Section; Example; Solution; The Shape of the Beam; The New Law; Examples.

Gifts have also been received from the following:

Adams, Arthur L. 1 pam.
Alaska Mexican Gold Min. Co. 2 pam.
Alaska United Gold Min. Co. 1 pam.
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Arlington, Mass.—Town Officers. 17 vol.
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Waddell, J. A. L. 1 pam.
Wilmington, Del.—Water Dept. 1 pam.
Worcester Polytechnic Inst. 1 vol.
Ziffer, E. A. 1 vol.

BY PURCHASE.

Electrotechnik in Einzeldarstellungen. Unter Mitwirkung hervorragender Fachmänner Herausgegeben von Dr. Gustav Benischke. Vol. I. Braunschweig, Friedrich Vieweg und Sohn, 1902.

Die Wechselstromtechnik. Herausgegeben von E. Arnold. Vol. I. Berlin, Julius Springer, 1902.

A Systematic Method of Calculating the Dimensions of Direct-Current Dynamo-Electric Machines. By Carl Kinsley. Chicago, The University of Chicago Press, 1903.

Secondary Batteries: Their Theory, Construction and Use. By E. J. Wade. New York, The D. Van Nostrand Co.; London, "The Electrician" Printing and Publishing Company.

Wireless Telegraphy. A Popular Exposition. By G. W. Tunzelmann. Third Edition. London, The Office of "Knowledge," 1902.

Supplement to the Directory to the Iron and Steel Works of the United States. Containing a Classified List of Leading Consumers of Iron and Steel in the United States. Compiled by the American Iron and Steel Association. Corrected to January, 1903. Philadelphia, The American Iron and Steel Association, 1903.

Proceedings of the Purdue Society of Civil Engineering. 1896, 98, 1900-01. Purdue University, Lafayette, Ind., 1896–1901.

First Annual Report of the Wisconsin Engineers' Society, Containing Papers Read at the Annual Meeting Held at Appleton, March 30, 1897. No place, 1897.

Proceedings of the Annual Meeting of the Indiana Engineering Society, 1893 and 1896. South Bend, 1893–96.

Proceedings of the Iowa Civil Engineers' and Surveyors' Society at their Ninth Annual Meeting held at Ottumwa, Iowa, January 20–21, 1897. Glenwood, Iowa, 1897.

Eighteenth Annual Report of the Ohio Society of Surveyors and Civil Engineers, being the Transactions of the Society at its Eighteenth Annual Meeting Held in Columbus, Ohio, January 18, 19 and 20, 1897. Columbus, 1897.

Annual Report of the Association of Ontario Land Surveyors, 1889, 1892–1900. Toronto, 1889–1900.

Notes on Concrete and Works in Concrete. Especially written to Assist those Engaged upon Public Works. By John Newman. Second Edition, Revised and Enlarged. London, E. & F. N. Spon; New York, Spon & Chamberlain, 1894,

Pumps and Pump Motors. A Manual for the Use of Hydraulic Engineers. By Philip R. Bjorling. 2 vol. London, E. & F. N. Spon; New York, Spon & Chamberlain, 1895.

The Principles, Construction and Application of Pumping Machinery (Steam and Water Pressure). With Practical Illustrations of Engines and Pumps applied to Mining, Town Water Supply, Drainage of Lands, etc., also Economy and Efficiency Trials of Pumping Machinery. By Henry Davey. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1900.

SUMMARY OF ACCESSIONS.

April 8th to May 12th, 1903.

Donations (including 41 duplicates and 1 number completing volume of periodical)	385
By purchase	27
Total	412

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
AVERILL, FRANK LLOYD. Structural Engr., Office of Superv. Archt., U. S. Treasury Dept. Washington, D. C	Assoc. M.	Jan. 6, 1897
	M.	May 6, 1903
BOSLER, HARRY SHERMAN. 209 Houston St., Chattanooga, Tenn		Feb. 4, 1903
DART, CARLTON ROLLIN. Bridge Engr., San. Dist. of Chicago, 555 Monroe St., Chicago, Ill		May 6, 1903
EMMONS, CHARLES MORTON. Asst. Engr., Penn. Bridge Co., Beaver Falls, Pa		April 1, 1903
FOSTER, ERNEST HOWARD. Vice-Pres., Power Specialty Co., 126 Liberty St., New York City		May 6, 1903
FRENCH, OWEN BERT. Asst., U. S. Coast and Geodetic Survey, Washington, D. C		April 1, 1903
HILLYER, WILLIAM ROSS. Asst. Commr. of Public Works, Borough of Richmond, Mundy Ave., West New Brighton, N. Y		May 6, 1903
LARSSON, CARL GUSTAF EMIL. Div. Engr., Eastern Div., Am. Bridge Co., Pencoyd, Pa. (Res., 148 Sumac St., Philadelphia, Pa.)		April 1, 1903
MCLEAN, ARCHIBALD. Engr. in Chg. of Maintenance, Brooklyn Bridge, 179 Washington St., Brooklyn, N. Y		May 6, 1903
MITCHELL, SAMUEL PHILLIPS. Chf. Engr., Am. Bridge Co. of N. Y., N. W. cor. 15th and Chestnut Sts., Philadelphia, Pa		April 1, 1903
OLMSTED ASHBEL EDWARD. Div. Engr., Rapid Transit Subway Constr. Co. of N. Y., 744 St. Nicholas Ave., New York City		May 6, 1903
POTTER, CHARLES LEWIS. Capt., Corps of Engrs., U. S. A., P. O. Box 204, Memphis, Tenn		April 1, 1903
RICH, ISAAC. Asst. Engr., N. Y., N. H. & H. R. R., Room 469, Terminal Station, Boston, Mass		May 6, 1903
ROHWER, HENRY. Chf. Engr., Mo. Pac. Ry. Co., 5900 A Clemens Ave., St. Louis, Mo		April 1, 1903
RUST, HENRY, BEDINGER. Supt. Constr., Colorado Fuel & Iron Co., 55 Block M, Pueblo, Colo.	Assoc. M.	April 6, 1898
	M.	April 1, 1903
SIRRINE, JOSEPH EMORY. Box 98, Greenville, S. C.	Jun.	June 20, 1893
	Assoc. M.	May 4, 1898
	M.	May 6, 1903
WASON, LEONARD CHASE. Pres., Aberthaw Constr. Co., 8 Beacon St., Boston, Mass. (Res., 199 Harvard St., Brookline, Mass.)	Assoc. M.	April 3, 1901
	M.	April 1, 1903

ASSOCIATE MEMBERS.

	Date of Membership.
BREED, CHARLES BLANEY. 54 Hamilton Ave., Lynn, Mass....	May 6, 1903
CONNICK, HARRIS DE HAVEN. Asst. Engr., Dept. of Public Works, City Hall, San Francisco, Cal. ..... Jun.	Jan. 3, 1899
..... Assoc. M.	Feb. 4, 1903
CREW, CHARLES CORWIN. Res. Engr., St. L., K. C. & C. Ry., Versailles, Mo	April 1, 1903
DE VOU, JAMES LAIRD. Asst. to Chf. Engr., Am. Bridge Co. of N. Y., Pencoyd Club, Wissahickon, Philadelphia, Pa..	April 1, 1903
FRANKLIN, BENJAMIN. 907 Crozer Bldg., Philadelphia, Pa....	April 1, 1903
GIFFORD, ROBERT LADD. Pres., Ill. Eng. Co., 319 Manhattan Bldg., Chicago, Ill.....	May 6, 1903
HAIGHT, HORACE DE REMER. Engr. for Thos. Prosser & Son, 15 Gold St., New York City.. Jun.	May 1, 1900
..... Assoc. M.	Feb. 4, 1903
HARTIGAN, FREDERICK LAWRENCE. 6233 Woodlawn Ave., Chicago, Ill.....	May 6, 1903
KIMBALL, WILLIAM HALE. Davenport, Iowa.....	April 1, 1903
KNAPP, HERMANN MERIWETHER. Designing Engr., Am. Bridge Co., Pencoyd, Pa.....	May 6, 1903
MILLER, GEORGE SOTER. Fort Wright, Fishers Island, N. Y..	April 1, 1903
NEFF, FRANK HOWARD. Prof. of Civ. Eng., Case School of Applied Science. 860 Doan St., Cleveland, Ohio... ...	May 6, 1903
OMBERG, JAMES ADOLPHUS, Jr. City Engr., Memphis, Tenn..	April 1, 1903
PINCOMBE, WILLIAM EDWIN. East Indian Ry., Calcutta, India.	Feb. 4, 1903
SESSER, JOHN CORNELIOUS. Chf. Engr., Nebr., Kans. & Gulf Ry. Co., 303 New England Bldg., Kansas City, Mo..... Jun.	Sept. 5, 1899
..... Assoc. M.	April 1, 1903
SKELLY, JAMES WILLIAM. U. S. Engr. Depot, Ft. of Arsenal St., St. Louis, Mo..... Jun.	May 2, 1899
..... Assoc. M.	April 1, 1903
TREADWAY, HOWARD PLATT. Pres. and Engr., Kansas City Bridge Co., 412 Massachusetts Bldg. Kansas City, Mo.....	May 6, 1903

ASSOCIATES.

UMSTEAD, CHARLES HENRY. 30 Austin St., Portsmouth, N. H.	May 5, 1903

JUNIORS.

DIAMANT, ARTHUR HERBERT. 4 East 97th St., New York City.	May 5, 1903
HAUSMAN, FREDERICK APPEL. Hotel Bridgeport, Bridgeport, Pa.....	Feb. 3, 1903
HOLMES, EDWIN MERRITT. Engr. for The Spanish Am. Iron Co., Vinent Mines, Daiquiri, Santiago, Cuba	Mar. 31, 1903
MOORE, EGBERT JESSUP. 413 Gay St., Phœnixville, Pa	Mar. 31, 1903
ROBB, LOUIS ADAMS. 71 Lincoln Park, Newark, N. J.....	May 5, 1903
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WYCKOFF, CHARLES RAPELYEA, Jr. 185 Penn St., Brooklyn, N. Y.....	May 5, 1903

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HILL, THEODORE WILLIAM.....Newton Falls, Ohio.
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HUGHES, WILLIAM MACKENZIE.....Cons. Bridge Engr., 401 La Salle Sta., Chicago, Ill.
JACKMAN, HOWARD HILL.....2177 Washington Boulevard, Chicago, Ill.
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COSMUS, JOHN ALBERT.....Special Agt., Continental Fire Ins. Co., P. O. Box 187, Utica, N. Y.
CRANE, CLARENCE AUSTIN.....Cons. Engr., 765 Tremont Ave., New York City.
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DANA, RICHARD TURNER.....Civ. and Cons. Engr., 15 William St., New York City.
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THORNLEY, JULIAN.....Care, The Elec. Development Co. of Ontario, Ltd., Niagara Falls, Ont., Canada.

ASSOCIATES.

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SNYDER, CHARLES HERMAN.....212 Water St., Johnstown, Pa.
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RESIGNATIONS.

MEMBERS.	Date of Resignation.
MONCURE, WILLIAM	May 5th, 1903

DEATHS.

CARD, WILLIAM WARREN.....Elected Member, September 5th, 1883; died April 4th, 1903.
CLEMENT, VICTOR M.....Elected Fellow, January 8th, 1890; died April 28th, 1903.
GREENE, EDWARD APPLETON.....Elected Member, July 4th, 1888; died April 19th, 1903.
GURNEE, WALTER S.....Elected Fellow, May 10th, 1870; died April 17th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(April 8th to May 12th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brusseis, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

Essentials Necessary for Successful Practice in Bridge Engineering. J. E. Greiner, M. Am. Soc. C. E. (Extracts from lecture delivered before students of Cornell Univ.) (13) Apr. 9.
The Rio Grande Bridge of the El Paso & Southwestern R. R. near El Paso, Tex.* R. A. Thompson. (13) Apr. 9.
The Des Moines River Viaduct of the Mason City & Fort Dodge R. R., at Fort Dodge, Ia.* H. C. Keith. (13) Apr. 9.
New Railway Bridge over the Tyne.* (12) Apr. 10.
Types and Details of Bridge Construction.* Frank W. Skinner. (14) Serial beginning Apr. 11.
Theory and Calculation of the Two-Hinged Spandrel-Braced Arch. Alex. Rice McKim. (14) Apr. 11.
Drawbridge Calculations. Edward Godfrey. (13) Apr. 16.
The Paderno Viaduct, Italy.* (12) Serial beginning Apr. 17.
The Ouachita River Bridge, Missouri Pacific Railway.* (40) Apr. 17.
A Steel Truss Highway Bridge with Concrete Floor.* (14) Apr. 25.
Erection of the Manhattan Approaches to the Williamsburg Bridge.* (14) May 9.
Le Viaduc du Viaur (Ligne de Carmaux à Rodez).* R. Godfernaux. (30) Apr.

Electrical.

The Arcophone. R. A. L. Snyder. (42) Mar.
Telephone Service. S. J. Larned. (4) Apr.
The Development, Equipment and Operation of the Sub-Stations and Distributing Systems of the Chicago Edison Co. and Commonwealth Electric Co. Ernest F. Smith. (4) Apr.
Grounding of Alternate Current Systems. Geo. N. Eastman. (4) Apr.
The Engineering of Illumination.* Van Rensselaer Lansingh. (4) Apr.
Electricity Works of Tunbridge Wells.* (26) Apr. 3.
On the Application of Three-Phase Motors to the Electrical Driving of Workshops and Factories.* A. C. Eborall. (29) Apr. 3.
Laboratory Electric Furnace Equipment, Owens College, Manchester, England.* (27) Apr. 4.
Electrical Manufacture of Steel in Sweden.* G. Lindman. (27) Apr. 4.
Electrical Extensions at Willesden. (12) Serial beginning Apr. 10.
Sheet Steel for Static Transformers. Walter S. Moody. (27) Apr. 11.
De Forest Wireless Telegraph System. A. Frederick Collins. (27) Apr. 11.
Wireless Telegraphy in the United States. E. Guarini. (26) Serial beginning Apr. 17.
Some Notes on Electrically Driven Winding Engines.* (57) Apr. 17.
Vancouver Transmission Plant.* Wyatt H. Allen. (27) Apr. 18.
The Lodge-Muirhead System of Wireless Telegraphy.* H. C. Fyfe. (46) Apr. 18.
Insulating Materials: A Field for the Chemist. Max von Recklinghausen. (Paper read before the Amer. Electrochemical Soc.) (13) April 23.
Electric Safety Fuses. (26) Apr. 24.
The Development of Marconi's System of Wireless Telegraphy.* Emile Guarini. (19) Serial beginning Apr. 25.
Telephone Exchanges.* Arthur V. Abbott. (27) Serial beginning April 25.
Corrosion of Metals by Electrolysis. A. A. Knudson. (Abstract of paper read before the Amer. Electrochemical Soc.) (27) Apr. 25.
Development in Telephone Switchboard Equipment at Bloomington, Ill.* (27) Apr. 25.
Core Type Transformers.* (27) Apr. 25.
General Specifications for the Construction of Telephone Aerial Lines.* (27) Apr. 25.
The Telegraphone and the British Post-Office.* Herbert C. Fyfe. (46) Apr. 25.
The Cascade Water, Power and Light Co., Cascade, B. C., Canada. W. G. McConnon. (27) Apr. 25; (18) Apr. 25; (14) May 2.
Notes on Recent Electrical and Scientific Developments Abroad.* William J. Hammer. (3) Serial beginning May.
Small Water Powers with High Heads for Electric Lighting.* Thoburn Reid. (10) May.
The Central Avenue Power Station (Kansas City).* H. S. Badger and G. E. Schreiber. (64) May.
The Motive Power of the Future.* Horace D. B. How. (Abstract of paper read before the South Wales Inst. of Engrs.) (22) May 1.
The New Aberdeen Electricity Works.* (26) May 1.
Electricity Supply for Small Towns and Villages. (47) May 2.
The New Brussels Telephone Exchange.* (27) May 2.
The Blondel Oscillograph.* (27) May 2.
Electrical Equipment of the Farmer's Bank Building, Pittsburg.* L. L. Emerson. (14) May 9.
A Twenty-Ton Switching Electric Storage Battery Locomotive.* (16) May 9.
Improvements in the Du Bois Electric & Traction System.* (17) May 9.
The Arnold-Bragstad-La Cour Polycyclic Power Transmission System.* O. S. Bragstad. (27) May 9.

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* Illustrated.

Electrical—(Continued).

La Dactyle Électrique.* O. Rochefort. (32) Feb.
Note sur les Installations Hydro-Électriques de Rheinfelden, de Zurich et de Schwyz, en Suisse.* G. Herman. (30) Apr.
Fonctionnement de l'Éclairage Électrique sur les Réseaux de Traction. Maurice Soubrier. (36) Serial beginning April 10.

Marine.

On the Effect of Modern Accessories on the Size and Cost of Warships. W. H. Whiting. (Paper read before the Inst. of Naval Archts.) (12) Apr. 3; (11) Apr. 3.
On the "Lines" of Fast Cruisers.* C. C. P. FitzGerald. (Paper read before the Inst. of Naval Archts.) (11) Apr. 3.
Carbonic Anhydride Refrigerating Machinery for Marine Use.* S. H. Bunnell. (13) Apr. 9.
The Naval Boiler Problem: Test of the Hohenstein Boiler.* John Halligan, Jr. (From the *Journal* of the Amer. Soc. of Naval Engrs.) (13) Apr. 9.
The Screw as a Means of Propulsion for Shallow-Draft Vessels.* A. F. Yarrow. (Paper read before the Inst. of Naval Archts.) (12) Apr. 10; (11) Apr. 10.
The Ljungström Condenser as Applied to Marine Engines. William Cross. (Paper read before the Inst. of Naval Archts.) (12) Apr. 3; (11) Apr. 17.
The Ballasting of Steamers for North Atlantic Voyages.* S. J. P. Thearle. (11) Apr. 17.
Screw Steamer for Towing, Salvage and Fire Purposes.* (11) Apr. 17.
The Italian First-Class Battleship *Beneditto Brin*.* (12) Apr. 17.
Results of a Naval Inquiry as to Which is the Most Powerful Armor-Clad Afloat. (19) Apr. 18.
Corrosion in Metal Pipes on Board Ship. A. W. Stewart. (Paper read before the Inst. of Naval Archts.) (11) Apr. 24.
Marine Installations for the Carriage of Refrigerated Cargoes.* R. Balfour. (Paper read before the Inst. of Naval Archts.) (12) Apr. 24.
Les Machines du Croiseur Protégé Russe *Bogatyr*.* (36) Apr. 10.

Mechanical.

On the Use of Beaumont Oil as a Fuel. Henry H. Humphrey. (1) Mar.
The Handling and Storing of Iron Ore. Charles Piez. (2) Apr.
The Slip of Belts. J. Stormonth. (12) Apr. 3.
The Valuation of Coals. E. L. Rhead. (22) Apr. 3.
Coking Badly Caking Coal: A New Mechanical Process.* (22) Apr. 3.
Slotting and Drilling Machines.* Thomas R. Shaw. (47) Serial beginning Apr. 4.
Power Production by Gas Producers and Engines.* Robert W. A. Brewer, A. M. I. C. E. (Paper read before the Civil and Mechanical Engrs. Soc.) (47) Serial beginning Apr. 4.
Carbonic Anhydride Refrigerating Machinery for Marine Use.* S. H. Bunnell. (13) Apr. 9.
Blooming Mill of the Röchling Iron and Steel Works. (11) Apr. 10.
The Curtis Steam Turbine.* W. L. R. Emmet. (Paper read before the Amer. Philosophical Soc.) (17) Apr. 11; (27) Apr. 11; (64) May; (18) May 2; Extracts (14) Apr. 11.
The Locomobile Gasoline Car.* (46) Apr. 11.
The Mond Power-Gas Process.* (66) Apr. 14.
Queen's Engineering Works, Bedford.* (26) Apr. 17.
Power Plant for the New Government Building at San Francisco.* (14) Apr. 18.
The Design and Testing of Centrifugal Fans.* W. Gilbert, A. M. I. C. E. (Paper read before the Civil and Mechanical Engrs. Soc.) (22) Apr. 24; (47) Serial beginning Apr. 18.
The Pedrail—A New Type of Road Locomotive.* Herbert C. Fyfe. (46) Apr. 18.
Some Special and Peculiar Types of Vertical Boilers.* William H. Fowler, M. Inst. C. E. (47) Apr. 18.
Transmission of Power by Compressed Air. W. C. Popplewell, A. M. Inst. C. E. (47) Apr. 18.
Gas Manufacture for 1908 at the Old Kent Road. (66) Apr. 21.
Moving a 110-Ft. Steel Chimney.* (13) Apr. 23.
Measuring the Power Required for Sheet Rolling Mills. H. G. Manning, M. Am. Soc. M. E. (13) Apr. 23.
Chill Rolls; The Problems of Their Manufacture and Use. B. E. V. Luty. (20) Serial beginning Apr. 23.
Machinery for the Panama Canal.* Waldon Fawcett. (62) Apr. 23.
Wind-Engines at the Royal Agricultural Society's Ground, Ealing.* (11) Apr. 24.
Modern Development of the Steam Turbine.* Frank C. Perkins. (46) Apr. 25.
Blue Water Gas and Its Enrichment by the Peebles Oil Gas Process.* E. J. Brockway. (Paper read before the Eastern Counties Gas Mgrs. Assoc.) (66) Apr. 28.
A Chain with Detachable Links.* (13) Apr. 30.
The New Works of the American Turret Lathe Mfg. Company.* (20) Apr. 30.
The Manufacture of Slag Bricks and Slag Blocks. Edwin C. Eckel, Assoc. Am. Soc. C. E. (13) Apr. 30.
Liquid Fuel for Power Purposes. Arthur L. Williston. (9) May.

* Illustrated.

Mechanical—(Continued).

Modern American Machine Tools, from the Standpoint of a Designer.* Charles H. Benjamin. (10) May.
Distributing Illuminating Gas at High Pressure: Some Examples from American Practice. F. H. Shelton. (10) May.
Valve Gear of the Porter-Allen Engine.* (64) May.
The Cotton Oil Industry in America.* D. A. Tompkins. (10) May.
Recent Steam Turbine Applications, with Data of Performances.* G. L. Parsons. (10) May.
Layout of Corliss Valve Gears.* Sanford A. Moss. (64) Serial beginning May.
The Hult Rotary Steam Engine.* (26) May 1.
The New Armour-Plate Mill at Creusot.* (11) May 1.
The Royal Agricultural Society's Windmill Trials.* (12) May 1.
Producer Gas. A. Humboldt Sexton. (47) Serial beginning May 2.
The Manufacture and Properties of Hollow Pressed Steel Car Axles.* Camille Mercader. (Paper read before the Iron and Steel Inst.) (20) Serial beginning May 7; (40) May 8; (18) May 9; Abstract (13) May 7.
Petroleum and Petroleum Lubricants. William F. Parrish, Jr. (Paper presented before the New England St. Ry. Club.) (17) May 9.
The Use of Reheaters in Compound Engines. (14) May 9.
A Double Drum Boiler.* (14) May 9.
Les Moteurs à Alcool au Concours International de 1902 (Resultats des Expériences Faites à la Station d'Essais de Machines). Max Ringelmann. (37) Mar.
Les Installations Nouvelles de la Sucrerie Centrale de Cambrai, à Escaudœuvres.* E. J. Brunswick. (33) Serial beginning Apr. 18.
Les Machines à Vapeur à l'Exposition de Düsseldorf.* P. F. Dujardin. (33) Apr. 25.

Metallurgical.

Electrical Manufacture of Steel in Sweden.* G. Lindman. (27) Apr. 4.
Metallic Conduction and the Constitution of Alloys. John Alexander Mathews. (62) Apr. 6
The New Furnaces at the Rio Tinto Works.* (16) Apr. 18.
Refining Gold by Electrolysis. (19) Apr. 18.
Smelting of Raw Sulphide Ores at Ducktown.* W. H. Freeland. (16) May 2.
The Krupp Works at Essen.* Day Allen Willey. (19) Serial beginning May 9.
L'État Actuel de Nos Connaissances sur la Constitution des Aciers au Carbone. Léon Guillet. (33) Serial beginning Apr. 4.
Les Nouveaux Procédés d'Extraction de l'Or: Procédé Riecken.* F. Schiff. (33) Apr. 11.

Military.

The Springfield Magazine Rifle, Model 1902.* (44) May-June.

Mining.

Electrical Coal-Cutting Machines.* Fredk. W. Hurd. (59) Vol. xxv, Pt. 3.
Electric Winding Engines.* E. Kilburn Scott, M. I. E. E. (22) Serial beginning Apr. 3.
A New Ventilating Fan and Engine at Littleton Colliery, Cannock.* (22) Apr. 3.
Outbursts of Firedamp in Mines. (57) April 3.
Central Electric Power Stations for Gold Mines. J. W. Kirkland. (Paper read before the Mech. Engrs. Assoc. of the Witwatersrand.) (47) Apr. 4.
Mining Methods on the Klondike.* Eugene Haanel. (16) Apr. 11.
Diamond Drilling. J. N. Justice. (Abstract of paper read before the Inst. of Mining and Metallurgy.) (22) Apr. 24.
Systematic Timbering in Continental Mines.* (57) Serial beginning Apr. 24.
Hoisting from Great Depths. Hans C. Behr. (16) Serial beginning Apr. 25.
Miner's Pthisis and Dust in Mines. William Cullen. (16) Apr. 25.
Chain and Pick Coal Cutting Machines.* H. S. Johnson. (16) Apr. 25.
The Daft and Williams System of Electrical Prospecting for Mineral Ores.* (27) Apr. 25.
The Stewart River Gold Dredge.* A. W. Robinson. (Paper read before the Canadian Mining Inst.) (68) Apr. 25; (16) May 2.
A Practical System of Mine Accounting. E. Jacobs. (9) May.
The Weir-Pittsburg District of the Kansas Coal Field.* W. R. Crane. (45) May.
Electric Mining Drills.* (45) May.
Present Practice in Gold Dredging. (45) May.
Third-Rail Tail-Rope Haulage System.* (45) May.
Timbering in the Collieries of Saxony and Austria.* (22) May 1.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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A NEW SAFETY EXPLOSIVE.

By Richard T. Dana, Assoc. M. Am. Soc. C. E.

To be Presented June 3d, 1903.

Since the days of Nobel's invention of dynamite, his mixture, or a close approximation to it, has been used in practically all industrial work requiring the use of a high explosive—until very recent years.

For some ten or fifteen years in Europe, and two or three years in this country, there have been coming into use some explosive compounds of the nitro-substitution class, so-called, which are claimed to have advantages over the dynamites, from the standpoints of non-freezability, safety in handling, and certain other points, varying with the particular compound.

In the summer of 1900, while on the New York Division of the Erie Railroad, the writer had occasion to recommend for trial an explosive having picric acid and sodium nitrate for the principal constituents, and which was advertised to be rather higher in power than 40% dynamite. There had recently been an explosion of dynamite in storage, for which no definite cause was discovered, and which was rather expensive; moreover, the 40% dynamite was thought to be a little weak for the rock to be handled, which was a hard metamorphic rock, called by the natives "bastard trap."

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

A box of this material, known as Joveite, was ordered, and careful tests made under the supervision of the writer, the results of which, with some supplementary ones which he made later, were as follows:

The material is a yellow powder, resembling corn meal, put up in cartridges similar to those of dynamite in size and shape. A quantity of the powder was placed on a rail and hammered with a sledge without result until after several trials a spark was struck, and the powder remaining on the rail burned up with about the rapidity of celluloid.

A stick was then fired into with a shot-gun without result, and then small quantities of equal bulk of Joveite and 40% dynamite were detonated on the corners of a wrought-iron plate, with a view to determine the intensity of explosion. The indication from two trials was that dynamite was a little the quicker. Several trials were made by mudcapping, in comparison with 40% dynamite, and no difference in the results detected. The powder was then used in the rock itself, and gave results practically identical, as far as work was concerned, with those from dynamite. Its general use was then recommended, and has been continued up to the present.

Joveite is somewhat lighter, bulk for bulk, than dynamite, the proportion being 2 to 3, and it was found that it would do just about the same amount of execution in the rock, bulk for bulk. This made the cost the same, or a little less, the price per pound being 11 or 12 cents. The material is a dry powder and therefore will not freeze. It has been used in the coldest weather without noticeable variation in strength or sensitiveness, and, as far as the writer knows, has never exploded accidentally.

As soon as the men became familiar with the material they began to take liberties with it, such as tamping it heavily in the hole. This gave rise to trouble, in the first few months of its use, for the cartridge in which it was put up was made of paper and frequently burst under this treatment, with the result that the powder was not properly confined in the hole and there were a number of cases of imperfect detonation. The powder is not easily detonated when wet, and, loaded in wet holes, its use was very unsatisfactory, dynamite being substituted; but, recently, the manufacturers have devised a water-tight cartridge with a cloth fiber, which admits of considerable tamping and distortion without becoming pervious. Loaded in this manner, its use is eminently satisfactory.

The men in the quarry had complained of the well-known effect of the nitro-glycerine fumes from dynamite. The writer made a careful examination of Joveite, in this particular, and did not succeed it getting a suspicion of headache from it, and he has heard no complaints in this respect, with one exception, which was at second-hand, and which he was unable to verify. When detonated, it has a distinctly perceptible odor, which is slightly suggestive of nitro-glycerine, but is not unpleasant.

The detonation is accomplished in the ordinary manner, by the use of a single-strength fulminate-of-mercury cap, either with a powder fuse or fired from a battery. In firing with a fuse, some trouble was experienced occasionally, from the fact that the material is inflammable. When the cap was inserted too far into the cartridge, the fire from the fuse itself would sometimes be communicated to the powder before the primer was fired, which resulted in a "flower pot." This was obviated by the use of electric fuses, or, on the other hand, by a little care in the setting of the powder fuse. It is to be regretted that in many cases owners of quarries still use the old Bickford type of fuse.

In the spring following the disastrous dynamite explosion at Forty-second Street, in New York City, the manufacturers of Joveite held a public exhibition of their product, at which they ignited a pile of boxes containing 600 lbs. of the explosive. The exhibitors said that their only feeling of nervousness was lest by some faint chance a mercury primer might have got among the boxes. The crowd stood about 80 yds. from the boxes, and it must be confessed that while the mass was taking fire the situation was decidedly interesting. About 150 or 200 lbs. of the explosive burned up immediately, scorching and charring the remaining boxes, which had not been broken open. These were then broken open and lighted, when the mass blazed up and was entirely consumed, with the evolution of a dense white smoke, and no very noticeable odor. Another interesting demonstration* was that of dropping a 200-lb. weight upon a box of the explosive in which were scattered bits of iron, nails, etc., resting on an anvil. The fall was about 30 ft., producing sufficient heat of friction and impact to ignite the powder.

A very important point, which the writer does not think has yet

* Mentioned in a letter by the writer, in *Engineering News*, January 22d, 1903.

been established definitely, is whether this explosive can be made to detonate without flame. It is claimed, by the manufacturers of a rival powder, that their product is absolutely flameless, and can be used safely in mine workings where there is a large quantity of dust, fire damp, etc., in the air. The manufacturers of Joveite say that, under special conditions, where a perfect detonation can be effected, they think that there is no flame from their product. In a mine, under service conditions, they do not claim entire immunity from flame. It has not yet been demonstrated, to the writer's satisfaction, that any explosion accompanied by evolution of heat is not, under some conditions, likely to be also accompanied by flame. Moreover, the question is still open whether fire damp or mine dust, with a proper admixture of gases, may not be detonated by shock. In the writer's opinion, the most instructive experiments with Joveite were witnessed by him at the company's laboratory in March, 1903.

Two sticks of the material were placed on the ground, end to end, the adjacent ends being about 3 ins. apart, and one stick only detonated. Afterward, the other stick was detonated by itself. Two sticks were placed side by side, 4 ins. apart, and one detonated without detonating the other. A stick was placed on the ground, and a mercury fulminate cap of single strength was fired ½ in. from and pointed at the center of the stick. The blast from the cap tore open the cartridge and threw out some of the powder without detonating it.

A quantity of the powder was sprinkled upon a red-hot iron plate. As the particles touched the plate they flashed into flame with a sputtering, or burned quietly until consumed.

A small quantity of the powder was placed in a small glass tube which was in turn inserted into the middle of another tube and placed between the poles of an extremely powerful spark machine. The machine was easily capable of generating a continuous spark 14 ins. long, and was so powerful that it could not be operated for more than a few seconds at a time without burning out the heavy rubber insulation from the copper wires. When the spark was generated, it perforated the smaller glass tube, about 1½ ins. in length, longitudinally. The effect of the spark on the explosive was to fuse it and burst the tube. Most of the Joveite was burned, and none of it detonated.

A description of the process of manufacture of Joveite, kindly fur-

nished by Mr. Frank P. Harris, Chemist of the company, is as follows:

The powder is composed of a mixture of nitro-naphthalenes, nitro-phenols, and a metallic nitrate.

The proportions are as follows:

	No. 1.	No. 2.	No. 3.
Nitro-naphthalenes	9	10	8
Nitro-phenols	14	24	30
Metallic nitrate	77	66	62

Picric acid is used for the nitro-phenol, and is what gives the powder its yellow color. It should be noted, in passing, that this substance stains the hands of the workmen using it. The stains are almost impossible to avoid in using, unless the whole sticks, paraffined, are used, and are exceedingly difficult to remove with the ordinary materials at the workman's command. The yellow stains are not easily visible by artificial light. Picric acid is soluble in alcohol and ether.

The metallic nitrate is dried thoroughly by means of a rotating-drum dryer, screened, and conveyed to a steam-heated room to be kept from absorbing moisture.

The nitro-napthalenes are first melted in a steam-jacketed kettle, and stirred by paddle arms, at the temperature of boiling water. Then the nitro-phenols are put in and melted, and, finally, the metallic nitrate, in the form of a dry powder, is stirred thoroughly with the other ingredients. After a time allowed for thorough mixing, the powder is removed to mechanical screens and there granulated to a free-running powder.

By using the nitro-napthalenes in this way it is possible to melt the nitro-phenols at a safe temperature, while the presence of nitro-naphthalenes in the finished product renders it quite insensitive to shock. By coating the grains of the metallic nitrates with the mixture of the nitro ingredients, the nitrates become protected from the atmosphere as by a varnish, for, while the nitro-phenols are slightly soluble in water, they are not deliquescent.

The quality of the powder depends wholly on the purity of the ingredients and the intimacy with which they are mixed.

The granulated powder is then packed in shells of various lengths and diameters, made of strong cloth-lined paper, and dipped in a paraffine solution, which renders them water- and moisture proof.

The finished shells are packed in wooden boxes, with no precaution as to jar or shock. The powder is also sold as a free-running powder, put up in water-proof bags.

"Spontaneous combustion is not possible. There is no instance known of a nitro-substitution compound, such as these, undergoing spontaneous decomposition; though the first of these bodies was discovered in 1788, and they have since been largely used in the arts."

Picric acid is $C_6 H_2 (N O_2)_3 O H$,
Sodium nitrate is $Na N O_3$,
Nitro-naphthalene is $C_{10} H_7 N O_2$.

The action of this material, taken together with its insensitiveness, would seem to indicate that it detonates rather more slowly than dynamite, and, if this may be said of any detonation, progressively.

The writer has considered this material in comparison with other high-power explosives in use, viewed in the light of the following considerations:

Any high explosive belongs to one of two general classes:

(1)—Explosives proper, which may be considered as represented by the "mixtures," such as gunpowder and the chlorate mixtures; and

(2)—Detonating "compounds," including the nitric derivatives, guncotton and nitro-glycerine, and the nitro-substitution compounds, such as Joveite, Masurite, Lyddite, Bellite, Securite, the Volney powders, Emmensite, Gelbite and Roburite. The line of demarkation between an explosion and a detonation is by no means absolutely defined in all cases, but, on the other hand, there are numbers of cases which are undoubtedly on one side or the other of this line. Black gunpowder, for example, is readily exploded when confined by heat properly applied in the form of a spark. It is exceedingly difficult to detonate, however, without the admixture of a high explosive to give it sudden and great pressure. Iodide of nitrogen is readily detonated by a fly walking on it, but it is questionable whether it has actually been exploded progressively.

In the case of gunpowder, the explosion is the result of combustion instituted and propagated by a high temperature, in other words, heat. The cause of detonation is not quite so clear. Abel's theory of "Sympathetic Explosion" was that it was due to synchronous vibrations, the originating cause of the detonation being the synchronism between the vibrations produced by the body which provokes the

detonation and those which the first body would produce in detonating. Mr. Eissler, in his work on "The Modern High Explosives," states that:

"The propagation of explosions by influence is not made in virtue of an undulatory movement, which is a complex motion of a chemical and physical order in the midst of the explosive substance which is decomposed, while it is purely physical in the midst of intermediary substances which suffer no decomposition. But that which distinguishes this sort of movement of the vibrations, properly so called, is, first of all, the magnitude of the mechanical energy which it transmits; it is also the unique character of the explosive wave which is propagated in contra-distinction with the multiplicity of sonorous waves. Finally, it is essential to observe, that the explosive material does not detonate because it transmits the movement, but, on the contrary, because it arrests it, and because it transforms on the spot the mechanical energy into thermal energy, capable of suddenly raising the temperature of the substance up to the degree which will produce its decomposition."

A stick of Joveite, placed against an iron plate and fired upon with a steel-jacketed bullet from a high-powered rifle, will detonate. The impact of the bullet on the plate will generate considerable heat and at the same time set up a high order of vibration, neither of these agencies alone, as proved by the tests before mentioned, being adequate to produce that effect. The writer is informed that in the last-mentioned experiment a sheet of paper placed between the Joveite and the iron plate will nullify the effect.

The writer has concluded, then, that the statement made by the manufacturers of Joveite is correct, namely, that it requires for detonation a vibration of a certain quality and degree of intensity, together with a definite amount of heat.

The contrasted qualities of the safety explosives, as compared with dynamite, can most easily be considered by tabulating a number of the best-known characteristics of ordinary dynamite. These are as follows:

(1) Power;
(2) Cost; initial price;
(3) Rapidity of action;
(4) Facility and cost of detonation;
(5) Applicability to various conditions of work;
(6) Temperature of detonation;
(7) Freezing phenomena;
(8) Ease of transportation and cost;

(9) Ease of storage and cost;
(10) Flame from explosion;
(11) Fumes, and effects from handling;
(12) Specific gravity;
(13) Risks; divided into: (*a*) risks from proper handling; and (*b*) risks from improper handling.

There is no satisfactory way of comparing the power of different explosives from the view-point of efficiency in the rock, except by actual tests under working conditions. The ordinary method for rough comparison is to load a mortar with a known weight of explosive, and observe the distance or height to which a projectile will be thrown. Another plan is to explode a small quantity of material within a lead casket, and note the deformation of the lead. Neither of these methods gives comparable results, for the reason that the observed effect depends upon three factors: The rapidity of detonation, the volume of gases generated, and the temperature of the gases found.

The rational criterion of the strength of any explosive is, of course, the amount of energy (*i. e.* force × distance) which a unit quantity will develop. Commercially, this is of little value, because of the well-known laws of blasting. In rather hard rock which is not very seamy the higher grade of Joveite, called *3xx*, is, from all the evidences which the writer could gather, more efficient than so-called 40% dynamite. It appears to have considerably more energy, pound for pound, but does not deliver such a quick, shattering blow as the higher dynamites. When used under conditions comparable to those for 40% dynamite it should be loaded in charges corresponding with normal dynamite charges, bulk for bulk, and will then give probably more economical results. For certain kinds of tunnel work in extremely hard and tenacious rock, or where the rock is much seamed and fissured, the higher grades of dynamite are probably more efficient than the *3xx* grade of Joveite as at present manufactured.

The foregoing remarks apply, of course, only to the grades of Joveite examined by the writer. It will be noted that the highest of these grades contains only 30% of picric acid. There is every reason to suppose that it will be practicable to make a grade of Joveite, containing, perhaps, more picric acid, very much more powerful than the present product, for fused picric acid is practically Lyddite, one of the most

powerful explosive substances known. Ecrasite, a salt of tri-nitro-cresol, in the same family as the picric salts, is said to be in effect twice as strong as dynamite. It is said that it is "made in Germany."

The cost of detonating Joveite is the same as that for dynamite, the same primer being used. A point which is not yet generally appreciated by workmen is that Joveite and dynamite, through improper setting, will not always detonate as they should, and, as a result, much labor and money are wasted. The point of setting the sticks in contact and, as nearly as possible, entirely filling the hole, with the maximum safe amount of tamping, is often lost sight of. In the tamping, Joveite has a great advantage, as it may be tamped heavily.

The range of practicable application for the "safety explosives" is large. The writer is informed that Joveite has been used successfully to break up frozen iron ore on the cars, an application probably quite beyond the reach of dynamite.

It may be transported long distances readily, and used for such purposes as digging post-holes in frozen ground. It should not be difficult to apply it to the driving of piles, the loosening of frozen earth and similar work.

The cost of transportation and storage of the safety explosives should be much less than with dynamite. In a railway collision, Joveite will presumably, at the most, burn up. In storage or transportation it is difficult to see where it is more dangerous than celluloid, except when adjacent to a box of fulminate caps.

The safety explosives may or may not be flameless, but the same thing is true of "carbo-dynamite" containing nitro-glycerine and charcoal.

The gases from the combustion of the picric acid compounds seem to be highly corrosive to iron and steel.

The following is a list of some of the dangers arising from the use of dynamite, which have been subdivided into two classes, and which, in the light of the facts outlined, point a striking moral:

(*a*) Dangers inevitable, even with reasonable care;

(1) Spontaneous explosion in storage;

(2) Lightning;

(3) Part of charge failing to go off and remaining undiscovered until exploded either by the sun's rays or by being struck by a tool;

(4) Train wreck;
(5) Drilling near missed hole;
(6) Flame. Fire-damp.

(*b*) Dangers incidental to the handling of dynamite as practiced every day;

(1) Dropping stick or box;
(2) Hole too small for cartridge; ramming down cartridge;
(3) Ramming too hard, or ramming with metal bar;
(4) Deepening missed hole;
(5) Returning to relight fuse;
(6) Testing the end of a hole with an iron bar after a blast, to see if any of the charge remains;
(7) Forcing primer into cartridge;
(8) Ramming in the first ball of tamping clay;
(9) Breaking a cartridge when near the freezing point;
(10) Stepping upon particles of explosive;
(11) Thawing in tin over a fire;
(12) Thawing in front of kitchen fire;
(13) Thawing in the men's boots or shirts;
(14) Thawing in an oven;
(15) Hot water containing dynamite placed on a blacksmith's fire;
(16) Thawing with candle;
(17) Reheating water which has been used in thawer;
(18) Throwing on ground water which contains nitro-glycerine from thawing cartridges;
(19) Rubbing cartridge in hands to complete thawing;
(20) Cartridge left in pocket of garment hung before fire to dry;
(21) Having cartridge and primer near each other when not in use;
(22) Destroying material not considered desirable.

Numbers (2) and (6) are the only cases under Class (*a*) in which danger is to be apprehended from the use of Joveite. The experiment of passing a high-tension spark through it is perhaps as near to natural conditions as it is practicable to get in the laboratory, but the writer is not satisfied that Joveite may not be exploded by lightning.

Under Class (*b*) we have (5) and (21) as the only elements of danger mentioned above which are common to dynamite and Joveite.

This list of "dangers" which the writer has complied is, of course, not complete, but it should be pretty well distributed over the field of ordinary engineering practice.

A rival product to Joveite, previously mentioned, is Masurite, which the writer has not tested personally. It resembles Joveite, and is claimed, doubtless with justice, to be very insensitive to shock, heat, percussion, concussion, an electric spark, etc. The composition is secret, but it contains a large amount of ammonium nitrate. It is claimed to be about as strong, bulk for bulk, as dynamite of corresponding grade, and to be not only flameless but non-inflammable. The cartridge is of paper, as at present made, and is probably subject to the same objections as the early Joveite cartridges before the adoption of cloth fiber. It will not detonate properly when wet, and requires a double-strength primer. An important objection to it is in the fact that the material cakes, and in that condition will not detonate readily, but when being loaded, the cartridges must be thoroughly rolled between the hands. With reference to the claim that this material is non-inflammable, the point suggests itself whether in a large fire, accompanied with much smoke and carbon in suspension, ammonium nitrate would not form a highly explosive mixture. This point the writer will not attempt to discuss.

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PAPERS AND DISCUSSIONS.

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AN EXPERIMENTAL STUDY OF THE RESISTANCES TO THE FLOW OF WATER IN PIPES.

By Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E.

To be Presented September 2d, 1903.

Before proceeding to the presentation and discussion of the experimental data upon which this paper is based, it may be of interest to describe briefly the reasons which have led the writers to make the treatment as broad as the title indicates.

As graduate students in Cornell University, the writers had been associated in experimental hydraulics for a year and a half before the investigations to be described were begun. During that time they had experienced a number of surprises in an investigation on the effect of curvature on the flow of water in pipes,* and the necessity of refraining from jumping at conclusions, with little or no experimental evidence, had impressed them more and more as the work advanced.

In 1900, Gardner S. Williams, M. Am. Soc. C. E., Engineer in Charge of the Hydraulic Laboratory of Cornell University, made

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 295.

an investigation,* from which one of the most interesting conclusions drawn was that the power of the velocity, with which the loss of head in water pipes varies, is dependent on the diameter of the pipe, being about 1 for very small tubes and increasing to about 2 for large pipes such as used ordinarily in the practice of the civil engineer.

For pipes below ½ in. in diameter, the value seemed to drop rapidly, while for pipes above that diameter the plotting showed a very gradual rise. However, the experimental results in the region where the most rapid change in the power seemed to occur were too few to give that feeling of entire confidence which is evident in the case of most of the commonly accepted laws of Nature. The desirability of further evidence was first pointed out to the writers by Professor Williams, and it is due to his interest in the matter, and to the true university spirit displayed by the College of Civil Engineering of Cornell University, that the writers were enabled to undertake experiments which, whatever their final aim became, had, as their primary object, the determination of the law governing the flow of water in small pipes.

The writers entered upon the investigation with the feeling that the small sizes of the pipes to be experimented upon would in no respect vitiate the results, from an engineering point of view. As will be shown later, the nature of the apparatus and the method of experimentation were to be such as to secure a high degree of accuracy in all the measurements. The writers, in their studies on the effect of curvature, had reached the conclusion that, in the manner of flow, there is practically no difference between a 2-in. and a 30-in. pipe. They expected, therefore, that much might be learned from the results of a comprehensive set of experiments on small pipes.

In addition to whatever light might be thrown upon the general subject of the flow of water in pipes, as ordinarily understood, the writers saw here an excellent opportunity to pursue their studies on the effect of the temperature of the water upon the loss of head, and hence upon the discharging capacity of pipes. The accepted idea in this matter is that the effect is negligible in pipes of commercial size. The writers had been led to question this, from their work on a 2-in. pipe,† and they saw in the experiments to be described a means of

* *Journal* of the Association of Engineering Societies, Vol. XXVI (Mar., 1901), p. 185.
† *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 313.

forming an idea concerning, or even of predicting the effect in large pipes.

Soon after beginning the experiments it was found that the power of the velocity, with which the loss of head varies, remains almost constant for the fifteen pipes of different sizes, but all of the same material (seamless-drawn brass); or, in the formula,

$$H = mV^n,$$

where H is the loss of head and V the mean velocity of the water in the pipe, the value of n was found to remain nearly constant for all the pipes. This somewhat astonishing fact appeared at first to be irreconcilable with the results of the investigation by Professor Williams; but, fortunately, the writers' experiments covered a considerable range of velocities, and it was soon found that the group of experiments on small brass and glass pipes (by Jacobson), upon the indications of which Professor Williams, with considerable justification, had placed great confidence, were all made with velocities below the "critical velocity," in which region the value of n is about 1. Hence the results were not comparable with results of experiments made under ordinary, or "above critical velocity," flow. This phenomenon will be discussed more fully later.

The fact that the value of the exponent of V was found to be almost constant for pipes ranging from $\frac{1}{10}$ in. to 2 ins. in diameter would have been sufficient of itself to warrant an investigation into the indications of reliable experiments on large, smooth pipes; for the smallest of these sizes bears the same relation to the largest as a 2-in. pipe bears to a 40-in. main (see Fig. 1, Plate XXXVII). If this were the only argument for entering on such a study, the writers feel that they would well deserve the flood of criticism which is ever threatening those venturous persons who presume to affirm that the same laws of Nature control the flow of water in the smallest pipes in the laboratory and in the largest supply mains running over hill and dale. In this paper it is aimed to present a few additional arguments which may serve to make such an affirmation appear a little less ridiculous than heretofore.

After the experiments had progressed far enough, and several different temperatures of water had been experimented upon for each of the pipes, it became evident that there is nothing to support the notion that the effect of temperature is negligible in large, smooth

pipes. In fact, the indications were found to point to such a considerable effect on pipes of large size that the limits of error which most hydraulic engineers would assign to the best formulas in use (all of which neglect temperature effect) are exceeded several times over, owing to the temperature factor alone.

The results of the brass-pipe experiments showed such harmonious relations that the writers were led to undertake some experiments on pipes which were less ideal and more practical. For this purpose five galvanized-iron pipes, ranging from ¼ in. to 1 in., commercial sizes, were chosen. While these experiments were conducted with the same care and precision as those on the brass pipes, and while each pipe by itself gave a consistent set of results, yet, between these results for the different pipes, there was a surprising lack of harmony, if it be assumed that all pipes were of the same degree of roughness. In short, the value of n, the exponent of V, in the formula $H = m\ V^n$, was found to vary so much for pipes nominally and apparently of the same kind that the writers saw here a consideration which might throw considerable light on the vagaries of the much-discussed, recorded pipe-experiments of modern and ancient times.

It may be well at this point to give a few reasons why the formula $H = m\ V^n$ is used. In the first place, the very fact that in the Chezy formula, $V = C\sqrt{r\,s}$, or, in the familiar textbook formula,

$$H = 4f\frac{l}{d}\frac{V^2}{2g},$$

the values of C and f are different for different velocities, shows that the power is something other than 2, if there is, indeed, any exponential law which is applicable.* And the writers venture to say that, up to the present time, there has not been evolved any theory which will assist in answering this question.

To be sure, there seems to be a more or less firmly grounded notion among some hydraulicians that the laws of gravity decree that the hydraulic slope or the loss of head must vary as the square of the velocity. The fallacy of this has been shown very clearly by Professor I. P. Church,† Assoc. Am. Soc. C. E., who emphasizes the fact that the question concerns primarily the relation between the velocity and the resistances, or "friction," and through this, as an entirely de-

* See discussion by Allen Hazen, M. Am. Soc. C. E., in *Journal* of the Association of Engineering Societies, Vol. XXVI (1901), p. 163.

† In *Engineering News*, Vol. XLVI, p. 332.

pendent matter, the relation between the velocity and the hydraulic slope. An illustration may make the point clearer. It is quite possible, by the use of compressed air, to maintain a high velocity in a very long pipe laid on an absolutely level grade with just enough head of water at the entry to keep the pipe full. Now, it is at once apparent that the law of a falling body has nothing to do with the relation existing between the pressure in the compressed-air chamber and the velocity of the water in the pipe. In fact, the force of gravity alone, in this case, would cause no flow at all.

In the absence of any theory, the only thing to do is to study the indications of experiments of known accuracy. These should embrace a wide range of velocities and several different degrees of roughness. The records of many such experiments have been before the engineer for a number of years, as have been also the records of investigations dealing with the question of exponents other than 2 for the velocity, or other than $\frac{1}{2}$ for the slope and the diameter (or the hydraulic radius). Unfortunately, the formulas with fractional exponents, which have been proposed from time to time, have been regarded generally as approximations, little, if any, closer to the truth than the standard Chezy formula, and far less easy to apply. In fact, some engineers have been led to question whether or not water flows in a pipe according to any definite determinable laws whatsoever.

Now, the writers have investigated, by the method of logarithmic plotting of the observed losses of head with the corresponding velocities, experiments in which the velocity ranges from a fraction of a foot per second up to 44 ft. per second. Their own experiments, almost 800 in number, and including twenty-three kinds of pipe and hose, cover a range of velocity from $\frac{1}{10}$ ft. per second to 22 ft. per second. In all these experiments, and especially in those of known accuracy in all measurements, the logarithmic plottings yield straight lines. The slopes of these lines differ considerably among themselves, or, in other words, the losses of head vary as various powers of the velocities,* but, whatever the slope of the line, each pipe appears to have a definite law, expressible in the form,

$$H = m\,V^n.$$

The values of m and n are constant for a given pipe in a given condition for all velocities. The "coefficient of roughness" is entirely

* *Transactions*, Am. Soc. C. E., Vol. XLIX. p. 145.

provided for by them. These appear to be scientific facts, and the writers felt that they had no choice as regards the formula to be used. As has been stated already, there is no existing theory which is applicable; but the experimental evidence is quite conclusive.

It must not be inferred, from what has been stated, that the writers are opposed to the Chezy and like formulas, or, on the other hand, that they uphold the forms with fractional exponents for practical uses; but, for purposes of investigation, it would be most irrational to start with a formula which is known to be only an approximation, especially when the exact formula is just as easy to treat. But, after such an investigation is completed, on the actual showings of the experiments, it will be easy and quite proper to look for approximate forms which may be more convenient for the engineer to use. On this point, however, more can be said, and to better purpose, after the presentation of the experimental evidence.

Enough has been stated to indicate that the scope of the investigation, as planned originally, has been enlarged considerably, and for such reasons that the writers feel that the whole subject of the flow of water in pipes may be considered open for a treatment in which the aim is to present the facts, in their relations to one another, in a thoroughly rational and comprehensive manner. It is the purpose, as far as possible, to make all plottings bird's-eye views of the whole subject, so that the experimental results may show at a glance the probable laws which too often have been obscured by misleading approximate formulas, and unfortunate attempts to make the results of the roughest kind of measurements fit these formulas. In the general plotting, many results of such rough measurements have been included. In fact, the idea has been to consider all experiments which are on record in any recognized source of information. But it is believed that the method of plotting has reduced to the greatest possible extent the question of individual judgment, and has allowed each experimental result to have its merited influence in controlling the final conclusions.

Description of Apparatus.

The general plan of the pipe system experimented upon is shown in Fig. 1. The pipes were located in the basement of Lincoln Hall, the principal building of the College of Civil Engineering, Cornell

PLAN OF PIPE SYSTEM.
(SCALE DISTORTED.)

FIG. 1.

University. The system was fed through the 5 and 2-in. pipes. The former extended from an equalizing cylinder, which could be supplied either from a tank in the attic (the supply to which was controlled by a float-valve) or directly from the campus mains.* The pressures in the cylinder, under static conditions, were approximately 20 and 30 lbs. from the attic tank and the main, respectively.

All elbows, tees and auxiliary pipes are of galvanized iron except the plain iron steam-pipe header from which extend Pipes *VIII* to *XIII* and a pipe feeding Pipes *XIV*, *XV* and *XVI*. All piezometric fittings are of brass. Experimental Pipes *II* to *XVI* are of seamless-drawn brass, and Pipes *XVII* to *XXI* are of ordinary commercial, galvanized-iron stock. The fittings on all the pipes except Pipe *II*† are described herein.

Piezometric Fittings.—The individual pipe lengths of Pipes *III* to *XVI* are connected by piezometric couplings of special design. Each coupling is in two pieces which screw together in such a way that when the pipe is ready for experimentation the pressure is transmitted to an annular chamber through a continuous slit or break in the pipe $\frac{1}{100}$ in. wide. The details of the construction are shown in Fig. 2, and in Fig. 1 of Plate XXXVII. The latter is from a photograph of piezometric couplings on Pipe *III* and Pipe *XVI*, and shows also the comparative sizes of these two pipes. The lathe work inside these couplings is practically perfect, while the differences between the inside diameters of the pipe and the coupling where the faced end of the pipe screws up against a shoulder are generally not more

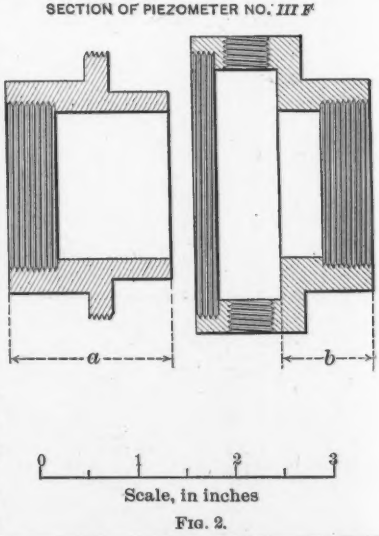


FIG. 2.

* The cylinder and the controlling valves are shown in Fig. 119, *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 297. The cycloidal mouthpieces between the cylinder and the 5-in. pipe and between the latter and the 2-in. pipe are described on p. 20 of the above-mentioned volume, and also on p. 180 of the *Journal* of the Association of Engineering Societies, Vol. XXVI, 1901, while Plate 25 in the latter gives a longitudinal section of this part of the apparatus.

† The piezometer fittings on Pipe *II* have been illustrated on p. 17 and in Plate IX, Fig. 1, *Transactions*, Am. Soc. C. E., Vol. XLVII.

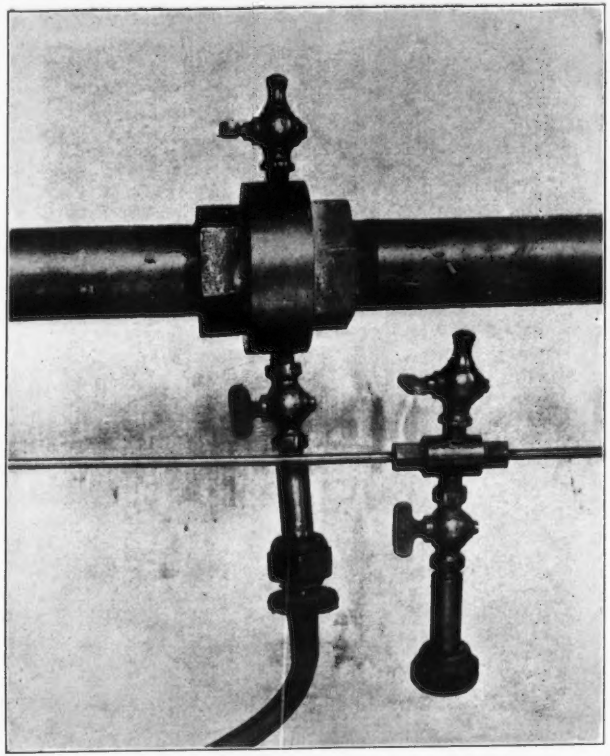


FIG. 1.—PIEZOMETER COUPLINGS. PIPES *III* AND *XVI*.

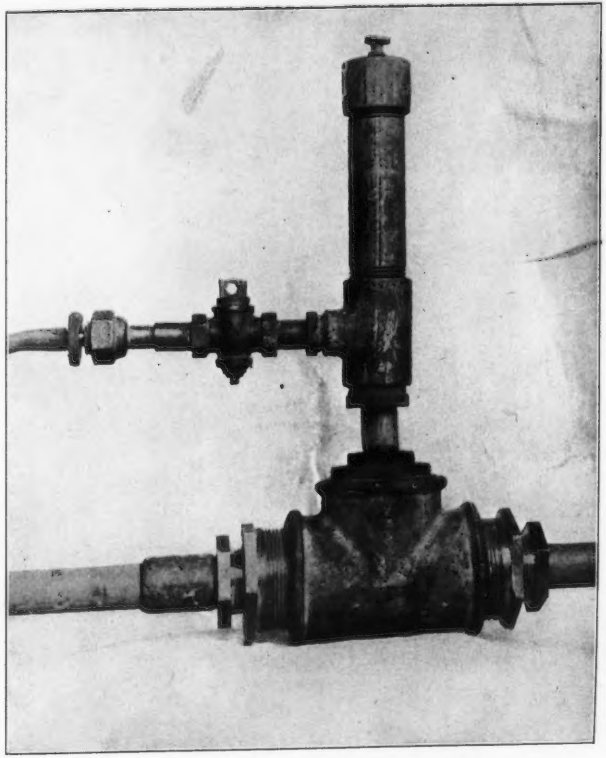


FIG. 2.—PIEZOMETER CHAMBER ON PIPE *XVIII*.

than $\frac{1}{1000}$ in., or the smallest amount which can be measured accurately with the ordinary micrometer calipers (see Table No. 1). Before the couplings were turned, the ends of all the pipes had been measured and the pipes matched. All threads were lathe-cut. In general, the pipes, when set up, left nothing to be desired, as far as nearly ideal conditions are concerned. The writers feel that without the excellent machine-work done by Mr. C. D. Cass, Mechanician to the Hydraulic Laboratory, the value of the experimental accuracy would have been very small. They desire to acknowledge their indebtedness to Mr. Cass for his accurate and conscientious work.

On account of the roughness of the galvanized pipes, as well as on account of the variable diameter, it was deemed best to avoid any form of joint at the point where the pressure was to be taken off. Accordingly, four $\frac{1}{8}$-in. holes, 90° apart, were drilled through the pipe walls $3\frac{1}{2}$ ins. from the ends of each experimental length. For the two smallest pipes the holes were $\frac{3}{32}$ in. in diameter, and the distance from the ends was $2\frac{1}{2}$ ins. The drill passed through both walls of the pipe at one setting. Thus, only two of the four holes had any burr inside. This was removed carefully with a rounded file. These holes in the finished piezometer fitting communicated to a chamber formed by a large tee slipped over the pipe and provided with a pair of brass bushings at each end. Between these bushings, and on the pipe, some candle wicking soaked with tallow was wound. When the smaller bushings were screwed up, the fitting was water-tight. A photograph of one of these fittings on Pipe *XVIII* ($\frac{3}{4}$-in. galvanized iron) is shown in Fig. 2, Plate XXXVII.* In order to avoid any error due to unequal diameters at the piezometers, all the experimental lengths were turned end for end, after the first set of experiments had been completed, and a second series was run with the reversed arrangement. In this way, also, the effect of any slight differences in the conditions of the flow at the two piezometers was eliminated. The up-stream, or entry, length of pipe was connected to the experimental length by an ordinary coupling. The ends of the pipe, however, were faced, and the threads were cut so that a butt joint was secured, avoiding the disturbing effect of the usual coupling on wrought-iron pipe where the ends do not come together.

* The air-chamber has a section like that shown on p. 17, *Transactions*, Am. Soc. C. E., Vol. XLVII.

TABLE No. 1.—Diameters (in inches) of Brass Pipes and Piezometers.

No. of Pipe.	Length No. 1.	Piezometer A.	Length No. 2.	Piezometer B.	Length No. 3.	Piezometer C.	Length No. 4.	Piezometer D.	Length No. 5.	Piezometer E.	Length No. 6.	Piezometer F.	Length No. 7.
III	1.4976 1.4986	1.498	1.4984 1.4976	1.498	1.4986 1.4983	1.498	1.4979 1.4982	1.498	1.4978 1.4984	1.498	1.4960 1.4988	1.498	1.4988 1.4980
IV	1.2465 1.2463	1.246	1.2376 1.2378	1.237	1.2361 1.2368	1.237	1.2378 1.2362	1.237	1.2378 1.2384	.....	.....	.....	.....
V	1.0693 1.0686	1.069	1.0531 1.0541	1.054	1.0543 1.0543	1.054	1.0539 1.0557	1.054	1.0539 1.0553	1.054	1.0531 1.0530	.....	.....
VI	0.8321 0.8310	0.8315	0.8313 0.8318	0.8315	0.8197 0.8201	0.819	0.8201* 0.8201	0.819	0.8191 0.8189	0.819	0.8189 0.8344	.....	.....
VII	0.6307* 0.6303	0.630	0.6297 0.6293	0.630	0.6298 0.6299	0.630	0.6303 0.6305	0.630	0.6307 0.6301	.....	.....	.....	.....
VIII	0.4976* 0.4982	0.498	0.4982 0.4977	0.498	0.5008 0.5006	0.500	0.5008 0.4998	0.500	0.5006 0.5008	.....	.....	.....	.....
IX	0.3764 0.3766	0.376	0.3763 0.3768	0.376	0.3750 0.3766	0.376	0.3766 0.3768	.....	.....	.....	.....	.....	.....
X	0.3207 0.3213	0.3215	0.3218 0.3221	0.3215	0.3215 0.3217	0.3215	0.3217 0.3213	.....	.....	.....	.....	.....	.....
XI	0.2817 0.2817	0.282	0.2813 0.2823	0.282	0.2821 0.2811	0.282	0.2811 0.2813	.....	.....	.....	.....	.....	.....
XII	0.2608 0.2613	0.261	0.2622* 0.2602	0.261	0.2652 0.2644	0.266	0.2652* 0.2654	0.266	0.2644 0.2661	.....	.....	.....	.....
XIII	0.2217 0.2209	0.222	0.2213 0.2220	0.222	0.2217* 0.2220	0.222	0.2217 0.2211	.....	.....	.....	.....	.....	.....
XIV	0.1807 0.1789	0.180	0.1801 0.1801	0.180	0.1800 0.1799	0.180	0.1799 0.1787	.....	.....	.....	.....	.....	.....
XV	0.1507 0.1492	0.151	0.1511 0.1522	0.151	0.1506 0.1526	0.151	0.1526 0.1514	.....	.....	.....	.....	.....	.....
XVI	0.1057 0.1081	0.107	0.1071 0.1083	0.107	0.1055 0.1073	0.107	0.1073 0.1051	.....	.....	.....	.....	.....	.....

Note.—The first of the two diameters under each length is for the up-stream end in the usual arrangement. This is also the marked end, except where an asterisk denotes that the unmarked end is up stream.

Measurements of Diameters.—From the ends of all the brass and galvanized-iron pipes there were cut sample rings from $\frac{1}{8}$ to $\frac{1}{4}$ in. long. Before cutting off the rings in the lathe, the ends of the pipe were faced, the tool being started on the inside wall of the pipe, thus securing a sharp, clearly defined edge, and avoiding entirely the burr which would result if the tool were started on the outside.

Four diameters were measured on each ring. The rings from the brass pipes were placed on the bed of a dividing engine, and readings were taken as the inner edges appeared under the cross-hair of the microscope. The bed advanced 1 mm. for each turn of the screw, and one two-hundredth part of a turn could be read directly from a graduated disc on the screw. The rings from the galvanized pipes were measured with small micrometer beam-calipers reading to one-thousandth of an inch.

The means of the four measured diameters on each ring, corresponding to the mean diameters of the ends of the brass pipes, are given in Table No. 1. The numbers refer to the position of the individual pipe lengths in the experimental arrangement, the lengths being numbered consecutively, beginning at the up-street end. In a number of cases a single piece of pipe was cut into two or three lengths. Hence the question as to the uniformity of diameter can be answered by direct evidence. The following list shows what lengths were cut from the single factory lengths.

III.—No. 7 was cut from No. 6
IV.— " 5 " " " " 2
V.— " 2 " " " " 5
VI.— " 4 " " " " 3
VI.— " 6 " " " a piece, the remainder of which was not used.
VII.—No. 5 was cut from No. 1
VIII.— " 2 " " " " 1
VIII.— " 5 " " " " 4
VIII.— " 3 " " " " 4
IX.— " 1 " " " " 2
IX.— " 4 " " " " 3
X.— " 1 " " " " 2
X.— " 4 " " " " 3
XI.— " 1 " " " " 2

XI.—No. 5 was cut from No. 4
XI.— " 3 " " " " 4
XII. — " 1 " " " " 2
XIII.— " 1 " " " " 2
XIII.— " 4 " " " " 3
XIV.— " 1 " " " " 2
XIV.— " 4 " " " " 3
XV.— " 1 " " " " 2
XV.— " 4 " " " " 3
XVI.— " 1 " " " " 2
XVI.— " 4 " " " " 3

If a pipe was cut into three pieces, the shortest piece was cut off first. All pieces were cut from the unmarked end of the factory length. The unmarked end of the original pipe became the unmarked end of the first piece cut off. Hence, the marked end of a short pipe cut from a factory length represents a section in the middle of the latter.

TABLE No. 2.—DIMENSIONS OF GALVANIZED PIPES.

No. of pipe.	Length, in feet.	Diameters, in Inches.					
		Nominal.	Standard.	By Calipers.		Water-filling method.	Accepted diameter.
				Marked end.	Unmarked end.		
XVII	18.751	1-in.	1.048	1.046 1.050*	1.037 1.044	1.031 1.037	1.036 1.042†
XVIII	17.496	¾-in.	0.824	0.789 0.850	0.799 0.850	0.815 0.849	0.805 0.850†
XIX	18.119	½-in.	0.623	0.627 0.631*	0.628 0.631	0.627 0.622	0.627 0.626†
XX	17.032	⅜-in.	0.494	0.493 0.489	0.502 0.482	....	0.498 0.486†
XXI	10.064	¼-in.	0.364	0.363 0.355*	0.345 0.345	....	0.354 0.350†

NOTE.—The lengths given in the table are for the experimental sections. For other lengths see Fig. 1.

* The marked ends are also the up-stream ends in the first or unreversed arrangement, except where an asterisk denotes the opposite.

† The experimental section.

In Table No. 2 are given the mean diameters of the galvanized pipes. In addition to the end caliperings, Pipes *XVII*, *XVIII* and *XIX* were measured by the water-filling method, special precautions being taken to avoid the adhesion of air to the walls of the pipe. The pipe was held vertically, and a stiff wire with a piece of cloth tied to the lower end was inserted until the cloth was near the bottom of the pipe. The pipe was then filled, and the wire was drawn up with a rotary motion. The pipe was finally filled flush, and the contained water was caught and weighed to the nearest $\frac{1}{1000}$ lb. Each pipe length was filled three times. Allowance was made for the small quantity of water which remained adhering to the inside walls of the pipe, a determination having been made.

Measurements of Lengths.—All lengths were measured with an accurate steel tape, and were checked by independent measurements. They are given in Fig. 1 and in Table No. 3. For the experimental sections, they are, in all cases, between the piezometric slits for the brass pipes, and between the piezometric holes for the galvanized pipes.

Methods of Experimentation.—All pipes were laid straight, and, where necessary, intermediate supports were used between the hangers on which the whole pipe system was supported. On account of their very small sizes, Pipes *XIV*, *XV* and *XVI* were laid on a board, and held straight by tacks. The hangers were levelled up carefully.

As shown in Fig. 1, there are fourteen valves to control the flow in the various experimental lines, several of which have two different sizes of pipes. It will be noticed that there is in all cases a considerable length of pipe up stream from the first piezometer, or Piezometer *A*. In fact, the writers had agreed that it is desirable to have an entry length of approximately two hundred diameters, in order to allow the flow to become normal. While this allowance is ample, it does not appear to be excessive. A length of one hundred diameters is, in the writers' opinion, hardly enough to allow the disturbances due to a curve at entry to die down fully.*

In order to get as large a range of velocities as possible, the down-stream sections of Pipes *VIII* to *XVI* were removed and replaced again from time to time. On several occasions Pipes *VI*, *VII*, *IX*, *XII* and *XIII* were entirely removed, in order to increase the discharge of the larger pipes ordinarily feeding into them.

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TABLE No. 3.—Brass Pipe—Lengths of Sections and Diameters.—See Fig. 1.

Pipe.	Section.	Length, in feet.	Accepted diameter, in feet.	Pipe.	Section.	Length, in feet.	Accepted diameter, in feet.
II.	*A-B*	57.496	0.1742	*IX.*—1	Reducer-*A*	6.08	0.03137
		57.518		2	*A-B*	6.068	
III.—1	Entry-*A*	10.08	0.12484	3	*B-C*	10.891	
2	*A-B*	14.031		4	*C*-Valve.	1.02	
3	*B-C*	14.032		*X.*—1	Entry-*A*	5.61	0.02679
4	*C-D*	10.681		2	*A-B*	6.719	
5	*D-E*	13.066		3	*B-C*	10.861	
6	*E-F*	6.152		4	*C*-Reducer.	1.075	
7	*F*-Valve.	6.73		*XI.*—1	Entry-*A*	4.96	0.02347
IV.—1	Entry-*A*	11.39	0.10887	2	*A-B*	7.396	
2	*A-B*	8.164	0.10311	3	*B-C*	10.894	
3	*B-C*	19.197		4	*C*-Reducer.	1.06	
4	*C-D*	17.073		*XII.*—1	Reducer-*A*	4.44	0.02176
5	*D*-Valve.	4.22		2	*A-B*	7.723	
V.—1	Entry-*A*	12.15	0.08908	3	*B-C*	2.133	0.02209
2	*A-B*	5.490	0.08785	4	*C-D*	8.891	
3	*B-C*	12.045		5	*D*-Valve.	1.04	
4	*C-D*	12.044		*XIII.*—1	Reducer-*A*	3.90	0.01846
5	*D-E*	11.903		2	*A-B*	8.202	
6	*E*-Reducer.	6.52		3	*B-C*	10.867	
VI.—1	Reducer-*A*	12.03	0.06930	4	*C*-Valve.	1.02	
2	*A-B*	12.057		*XIV.*—1	Entry-*A*	3.15	0.01498
3	*B-C*	5.835	0.06831	2	*A-B*	7.130	
4	*C-D*	6.134		3	*B-C*	10.876	
5	*D-E*	12.046		4	*C*-Valve.	1.02	
6	*E*-Coupling.	2.07	0.06889	*XV.*—1	Entry-*A*	2.62	0.01261
VII.—1	Reducer-*A*	9.87	0.05251	2	*A-B*	9.542	
2	*A-B*	12.079		3	*B-C*	10.868	
3	*B-C*	12.080		4	*C*-Valve.	1.02	
4	*C-D*	12.077		*XVI.*—1	Entry-*A*	2.68	0.00893
5	*D*-Enlargement to valve.	2.08		2	*A-B*	9.291	
		14.47		3	*B-C*	11.054	
VIII.—1	Entry-*A*	7.28	0.04149	4	*C*-Valve.	1.02	
2	*A-B*	5.031		.....	.....	.....	.....
3	*B-C*	3.160	0.04172	.....	.....	.....	.....
4	*C-D*	7.826		.....	.....	.....	.....
5	*D*-Reducer.	1.060		.....	.....	.....	.....

The differences of pressure between the piezometers were measured by either mercury or water gauges, of the differential type, the pressures being transmitted from the piezometers to the gauge columns by heavy, three-ply, cotton-insertion, rubber tubing. The scales of these gauges are divided into double centimeters and tenths, the hundredths being estimated. All gauges were supplied with riders to facilitate accurate reading of the menisci. The mercury gauges had three columns, and the water gauges had either two or three columns. Any of the gauges could be used as two-column gauges, if desired.

The water was discharged for measured intervals of time into a tank on one of three platform scales. One of these scales has a capacity

of 2 500 lbs., and is accurate to the nearest pound. Another has a capacity of 350 lbs., and is accurate to $\frac{1}{10}$ lb. The third is sensitive to $\frac{1}{100}$ lb. for weights not exceeding 50 lbs. The two smaller scales were calibrated with standard weights in the possession of the College of Civil Engineering. The largest was tested by comparison.

Thus, it was possible to secure the desired accuracy for the measurement of the discharge of the smallest of the pipes as well as the largest. In general, the attempt was made to secure an average accuracy of 1 in 500 in all measurements, whether of weight, time or gauge differences. For the highest velocities, a much greater accuracy has been obtained, while for some of the very lowest velocities, the weight or gauge difference was so small as to render the result accurate within only about $\frac{1}{2}$ of 1%, or, very rarely, within only 1%; but, for the vast majority of the experiments, it is believed that the attempted accuracy has been secured.

For many of the first experiments, the time was taken from a record sheet of a chronograph connected to the diverting arrangements and to the standard clock of the Astronomical Laboratory. It was found that the error in using an ordinary well-regulated watch was in general only a small fraction of a second. In fact, by using a small reading glass, the $\frac{1}{5}$-second beats can be seen quite distinctly on the second hand of the ordinary watch. Hence, for all the later runs, the time was taken with an ordinary watch, and it is believed that the time element is well within the attempted limit of accuracy.

During the time in which the flow was being measured, the gauge was read from six to twenty times. When the pressure was taken from the attic tank the columns were quite steady, but when connected to the campus mains, there was considerable vibration, yet not enough to impair greatly the accuracy of the readings. The main pressure was used, generally, only for the highest velocities, and hence the greatest gauge differences. The gauges were tested under no-flow conditions before and after, and frequently during, every series of runs. In general, no trouble was experienced. The columns came quickly to a common level. This condition of affairs the writers attribute to the complete control of the apparatus, the excellence of hose and gauge connections, and the great care taken to free the whole pipe system from air before starting any experiment. The temperature of the water for the first experiments was taken in the tank after the runs.

For these cases the temperature of the water was within 1 or 2° Fahr., of the temperature of the room. For the later experiments on Pipes *VIII* to *XVI*, and for all the experiments on Pipes *XVII* to *XXI* (of galvanized iron), the temperature was taken with a thermometer inserted in a stuffing-box, and with its bulb well within the pipe. The positions of these thermometer stuffing-boxes are shown in Fig. 1. The temperature was taken at the beginning and at the end of each experiment, and the mean value used, the differences being small. For Pipes *II* to *VII* it was found that the temperature in the pipes was the same as that in the tank after filling, within less than half a degree. Hence, the latter was taken, except at low velocities, when a small jar full of the water was caught just before and after each run and the temperature was read immediately.

Methods of Reduction.—In reducing weights to velocities the weights per cubic foot of distilled water at the observed temperature were taken from a table by the late Hamilton Smith, Jr., M. Am. Soc. C. E. These values are known to be correct within $\frac{1}{10}$ of 1% for the water used in the experiments.

In reducing observed heads on the differential water gauges a correction is necessary on account of the weight of a column of air of a height equal to the observed difference and under an average pressure of, approximately, $1\frac{1}{2}$ atmospheres. This amounts to a subtraction of approximately one five-hundredth of the observed differences. There is another correction on account of the difference between the temperature of the water in the gauge and that in the pipe, but this is very small, and is an uncertain amount, varying from nothing to a possible subtraction of one-six-hundredth of the observed difference. The correction actually applied, to cover these two items, is a subtraction of one five-hundredth of the observed difference for temperatures in the pipe below 60° Fahr.

For reducing observations on the mercury gauges, the "water equivalent" was obtained by direct comparison. A line of levels was run, and the elevation of the top of the attic tank above the zeros of the gauges was determined accurately. One observer measured the level of the surface of the water in the tank, while another took readings on the gauges in the basement. Eight determinations were made, with as many different heights of the water surface. The "water equivalent" was found to be 13.57 for mercury and water at 71° Fahr.

The eight determinations agreed within $\frac{1}{10}$ of 1 per cent. The weight of a column of air from the gauge to the attic was included in the calculation. Since the temperature of the room, and hence the specific gravity of the mercury in the gauges, was practically constant during the course of the experiments, the observed differences were corrected according to the specific gravity of the water flowing in the pipe. Thus all heads are reduced to water at the temperature of that in the pipe.

All reductions of weights to velocities, and of observed gauge differences to loss of head, in feet of water per 100 ft. of pipe length, have been checked by independent calculations. In addition, all results have been subjected to the test of two different methods of plotting, and any apparently wild cases have been recalculated. The writers have been pleased to find that the efforts to maintain a high degree of accuracy in all measurements have borne good fruit in the resulting indications.

Table No. 4 gives the data for the brass pipes, and Table No. 5 the data for the galvanized pipes.

Brass Pipe *III.*

30	*B–D*	2.70	*D–F*	2.69	70.2[a]	3.095	All heads for Pipe *III* were read on water gauges except in Experiment 194 and Experiments 308 and 309 for Sections *B–D* and *D–F* together. One experiment (309*b*.) read on water gauge.
31	"	1.96	"	1.96	70	2.576	
32	"	1.29	"	1.30	69.8	2.029	
33	"	0.709	"	0.716	69.8	1.431	
34	"	0.438	"	0.423	70	1.067	
35	"	16.04	*E–F*	16.05	68.8	8.473	
36	"	11.58	"	11.58	69.1	7.060	
37	"	8.40	"	8.34	69.1	5.887	
38	"	5.96	"	5.92	69.2	4.853	
39	"	3.47	"	3.41	69.1	3.568	
202	.....	.....	*B–F*	0.070	71.8	0.383	
203	.....	.....	"	0.291	71.8	0.870	
204	.....	.....	"	0.140	71.7	0.571	
194	*B–D*	17.74	*D–F*	17.70	68.8	8.994	
308	"	18.33	"	18.34	62.0	9.037	
309	"	15.70	"	15.83	62.5	8.280	
309*b*	"	15.89	.....	.....	62.5	8.280	
310	"	11.77	.....	.....	62.1	7.013	
311	"	8.77	.....	.....	62.1	5.947	
312	"	5.08	.....	.....	62.1	4.361	
313	"	2.25	.....	.....	62.2	2.744	
325	"	16.06	.....	.....	56.0	8.261	
326	"	13.40	.....	.....	55.6	7.443	
327	"	9.53	.....	.....	55.5	6.147	
328	"	6.19	.....	.....	55.5	4.814	
329	"	3.50	.....	.....	55.6	3.475	
407	"	16.78	.....	.....	46.0	8.265	
408	"	13.44	.....	.....	42.2	7.239	
409	"	9.28	.....	.....	41.1	5.864	Temp. Air, 76°. Temp. for Experiments 407 to 412 read in tank.
410	"	5.65	.....	.....	41.3	4.420	
411	"	2.69	.....	.....	42.0	2.893	
412	"	16.96	.....	.....	41.0	8.238	
544	"	16.96	.....	.....	36.0	8.098	
545	"	13.53	.....	.....	36.0	7.160	
546	"	10.26	.....	.....	35.6	6.109	
547	"	6.49	.....	.....	36.0	4.708	
548	"	3.18	.....	.....	36.9	3.128	
549	"	1.12	.....	.....	37.6	1.713	
550	*B–C*	19.36	.....	.....	35.5	8.738	

TABLE No. 4.

BRASS PIPE *II.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
1				4.155	36.0°	4.591	Length of section in Experiments 1 to 3 was 57.496 ft. For Experiments 4 to 34, and 714 to 717 length was 57.518 ft.
2				2.724	37.4	3.636	
3				1.342	36.0	2.412	
4				4.746	37.0	4.966	
5				3.637	36.0	4.290	
6				4.440	42.9	4.854	
7				3.963	41.0	4.550	All heads for Pipe *II* were read on water gauges.
8				2.813	41.5	3.737	
9				1.423	41.9	2.533	
10				0.437	42.0	1.281	
11				4.377	49.5	4.893	
12				3.737	49.4	4.473	
13				2.605	49.6	3.651	
14				1.545	49.6	2.713	
15				0.376	50.4	1.202	
16				4.281	55.2	4.889	
17				3.565	55.5	4.413	
18				2.662	55.5	3.734	
19				0.952	55.5	2.076	
20				0.285	....	1.035	
21				4.292	56.1	4.902	
22				2.711	58.5	3.774	
23				1.770	56.0	2.954	
24				0.861	56.0	1.959	
25				3.451	70	4.434	
26				5.341	69.8	5.701	
27				2.811	69.8	3.946	
28				1.604	69.8	2.886	
29				0.892	69.8	2.063	
30				0.562	70.2	1.590	
31				0.410	70	1.323	
32				0.273	69.8	1.043	
33				0.148	69.8	0.735	
34				0.095	70	0.548	
714				5.989	42.4	5.766	
715				1.742	39.0	2.830	
716				0.812	38.5	1.825	
717				2.895	37.0	3.746	

BRASS PIPE *V.*

48				4.146	70.3°	3.087	† Heads read on mercury gauges.
49				3.699	70.1	2.887	
50				2.707	70.1	2.415	
51				2.288	70	2.179	
52				1.885	70	1.959	
53				1.119	70	1.488	
54				0.546	70	0.942	
55				0.189	70	0.517	
209				0.312	71.6	0.751	
210				0.250	71.6	0.672	
211				0.133	71.6	0.447	
212				0.085	71.6	0.359	
203†		B–D	D–E	25.20	70.8	8.609	
204†		"	"	17.94	70.5	7.099	Temp., Air 71°.
205†		"	"	18.56	70.6	6.039	
206†		"	"	9.14	70.6	4.864	
209†		"	"	25.68	61.4	8.535	
200†		"	"	18.20	61.6	7.044	
201†		"	"	11.01	61.6	5.285	
202†		"	"	3.81	61.6	2.906	
347		D–E			54.5	7.090	
348		"			54.5	5.926	
349		"			54.5	4.624	
350		"			54.5	2.927	
351		"			55.0	8.208	
725		C–D			44	7.054	
726		"			42.1	5.133	
727		"			37.2	8.503	
728		"			36.6	7.900	
729		D–E			40	7.016	
730		"			39	5.395	
731		"			39.1	3.345	
732		"			35.8	8.295	
		B–D	D–E	4.179			
		"	"	3.721			
		"	"	2.713			
		"	"	2.275			
		"	"	1.895			
		"	"	1.137			
		"	"	0.597			
		"	"	0.185			
		B–D	B–E	25.20			
		"	"	17.94			
		"	"	18.56			
		"	"	9.28			
		"	"	25.86			
		"	"	18.26			
		"	"	11.08			
		"	"	3.90			
		D–E	"	18.67			
		"	"	18.72			
		"	"	8.88			
		"	"	4.01			
		C–D	"	24.67			
		"	"	19.87			
		"	"	11.56			
		"	"	28.49			
		"	"	21.36			
		D–E	"	20.17			
		"	"	12.73			
		"	"	5.49			
		"	"	27.93			

TABLE No. 4—(*Continued*).

BRASS PIPE *IV.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
40			*B–D*	5.61	69.0°	4.097	† Heads were measured in mercury.
42	*B–C*	4.06	*C–D*	4.06	69.1	3.384	
43	"	2.88	"	2.88	69.0	2.794	
44	"	2.03	"	2.04	69.0	2.279	
45	"	1.39	"	1.40	69.0	1.813	
46	"	0.52	"	0.52	69.0	1.019	
47	"	0.17	"	0.19	69.1	0.549	
205			*B–D*	0.145	72.2	0.506	
206			"	0.109	72.1	0.429	
207			"	0.255	72.0	0.695	
208			"	0.371	71.7	0.867	
259†	*B–C*	15.08	*C–D*	14.92	70.1	7.365(?)	Evidently a mistake of 5 seconds in time. $V=7.244$ therefore used.
260†	"	10.91	"	10.77	73.2	5.975	
261†	"	8.12	"	7.92	72.8	5.052	
262†	"	10.96	"	10.82	71.0	5.994	
303†	"	15.41	"	15.54	62.0	7.135	
304†	"	11.11	"	11.34	62.2	5.959	
305†	"	7.73	"	7.92	62.2	4.839	
306†	"	4.63	"	4.73	62.1	3.637	
307†	"	1.89	"	1.93	62.1	2.154	
303	"	15.43			62.0	7.135	
304	"	11.19			62.2	5.959	
305	"	7.85			62.2	4.839	
306	"	4.67			62.1	3.637	
307	"	1.89			62.1	2.154	
342	"	11.44			54.9	5.946	
343	"	8.30			54.7	4.960	
344	"	5.45			54.6	3.890	
345	"	2.39			54.5	2.427	
346	"	14.39			54.7	6.771	
718	"	12.11			46.5	5.977	
719	"	8.00			43.2	4.698	
720	"	2.82			43.0	2.584	
721	"	14.53			37.2	6.516	
722	"	9.97			37.0	5.269	
723	"	4.99			38.0	3.542	
724	"	2.12			38.5	2.167	

Brass Pipe *VII.*

50	*B–C*	31.09			70.1°	6.762	† Heads read in mercury.
51	"	26.04			70	6.101	
52	"	21.61			70	5.486	
53	"	12.61			70	4.028	
54	"	6.067			70	2.637	
55	"	2.140			70	1.447	
56	"	0.652			70.7	0.728	
195†	*A–C*	77.88	*C–D*	78.10	69.3	11.372	
196†	"	60.95	"	61.24	69.8	9.889	
197†	"	46.97	"	47.11	69.7	8.560	
198†	"	33.18	"	33.05	70.9	7.001	
199	*A–D*	0.440			71.3	0.648	
200	"	0.187			71.3	0.471	
201	"	0.087			71.8	0.218	
380†	*A–C*	78.29	*C–D*	77.04	72.0	11.375	After Experiment 201 Pipe *VII* was taken out and was allowed to remain empty. When set up again, the circulation through the piezometers was poor. Upon investigation, iron rust was found in the slits. These were easily cleaned.
381†	"	79.35	"	78.45	47.5	10.940	
382†	"	67.97	"	67.41	48.0	10.056	
383†	"	52.77	"	52.37	56.1	8.836	
384†	"	41.24	"	40.77	54.6	7.695	
385†	"	31.52	"	30.95	53.2	6.525	
386†	"	21.16	"	21.13	52.5	5.208	
387†	"	10.70	"	10.77	53.0	3.521	
388	"	0.342	"	0.348	85.8	0.538	
389	"	0.834	"	0.831	84.0	0.877	Temp., Air 76° in 383 to 387.
390	"	1.524	"	1.521	81.0	1.230	
391	"	1.203	"	1.206	81.0	1.075	
392	"	2.059	"	2.052	81.0	1.609	
393	"	3.316	"	3.282	77.0	1.881	
469†	"	79.38	"	78.10	40.8	10.686	Air, 71.6°.
470†	"	53.83	"	52.48	47.5	8.708	
471†	"	42.38	"	41.57	46.1	7.542	
472†	"	32.77	"	32 37	45.4	6.512	
473†	"	20.37	"	20.17	46.0	4.949	
474†	"	10.43	"	10.36	46.6	3.361	Air, 64°.
475†	"	81.76	"	80.35	38.2	10.745	
476†	"	67.69	"	66.31	37.8	9.711	
477†	"	49.12	"	48.45	37.5	8.098	
478†	"	35.33	"	34.89	37.3	6.680	

TABLE No. 4—(*Continued*).

BRASS PIPE *VI.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
41	*C–D*	40.15			69.0°	9.316	† Heads read in mercury.
42	"	28.93			69.1	7.712	
43	"	20.47			69.0	6.368	
44	"	14.38			69.0	5.194	
45	"	9.84			69.0	4.133	
46	"	3.66			69.0	2.322	
47	"	1.28			69.1	1.252	
180†	*A–D*	56.22	*D–E*	53.18	69.3	11.477 (For *D–E*)	11.146
181†	"	43.48	"	40.86	69.3	9.933 (For *D–E*)	9.647
182†	"	30.93	"	29.23	70.3	8.212 (For *D–E*)	7.975 Velocities in *A–B*.
183†	"	21.42	"	20.40	70.3	6.668 (For *D–E*)	6.476
184†	*B–C*	10.54	"	9.94	70.6	4.445 (For *D–E*)	4.317
185	"	59.97			69.3	11.477	
186	"	46.28			69.3	9.933	
187	"	32.84			70.3	8.212	
188	"	22.72			70.3	6.668	
189	"	11.12			70.6	4.445	After Experiment 193, Pipe *VI* was taken down and remained empty for a time. Upon setting again, the circulation through the piezometers was poor. Iron rust was found in the slits. These were easily cleaned.
190	*C–E*	1.56			70.9	1.501	
191	"	1.01			70.9	1.172	
192	"	0.722			71.1	0.962	
193	"	0.433			70.0	0.716	
399	*A–B*	30.11			51.5	7.705	
400	"	24.18			48.0	6.755	
401	"	16.71			47.0	5.470	
402	"	8.90			46.4	3.803	
403	"	1.58			46.6	1.404	
404	"	4.42			47.0	2.448	Air, 74°.
405	"	29.98			44.0	7.590	
406	"	13.19			44.0	4.720	
551†	*C–E*	58.40			36.3	11.055	
552†	"	45.72			36.2	9.638	
553†	"	34.72			37	8.223	
554†	"	24.99			37	6.841	
555†	"	11.54			37.6	4.352	
709†	*C–E*	38.60			79	9.382	
710†	"	39.72			53	9.114	
711†	"	56.74			48.7	11.125	
712†	"	58.90			38	11.131	
713†	"	27.25			45.1	7.270	

Brass Pipe *IX.*

64	*A–B*	73.36	.....	.....	69.1°	7.868 (?)	† Heads read in mercury.
65	"	59.15	.....	.....	69.5	6.777	* Columns vibrating badly.
66	"	39.29	.....	.....	69.6	5.371	
67	"	27.24	.....	.....	69.9	4.356	In Experiment 64 there was evidently a mistake of 5 lbs. in the weight. This was checked by Experiment 70. Velocity should be 7.652.
68	"	15.06	.....	.....	70.1	3.119	
69	"	6.38	.....	.....	70.5	1.928	
70	"	73.05	.....	.....	71.0	7.631	
176†	"	172.6	*B–C*	172.2	67.5	12.28	
177†	"	117.5	"	117.7	67.5	9.884	
178†	"	68.35	"	68.29	69.0	7.286	
179†	"	40.76	"	41.04	69.3	5.394	
275†	"	173.1	"	173.7	66.1	12.31	
276†	"	115.6	"	115.8	65.0	9.758	
277†	"	79.04	"	78.86	65.0	7.855	
278†	"	47.00	"	47.00	65.0	5.820	
283	"	22.24	.....	.....	66.1	3.882	
284	"	14.08	.....	.....	67.0	2.903	
285	"	7.375	.....	.....	67.0	2.011	
286	"	4.89	*B–C*	4.86	68.0	1.587	
287	"	3.57	"	3.53	68.2	1.343	
288	"	1.71*	"	1.59*	68.4	1.051	
289	"	0.95	"	0.96	68.6	0.849	
290	"	0.58	"	0.60	68.8	0.541	
291	"	0.31	"	0.33	69.0	0.291	
292	"	0.12	"	0.13	69.0	0.111	
338†	"	169.9	"	170.7	55.0	11.91	Air, 67°.
339†	"	130.4	"	131.3	55.5	10.27	
340†	"	78.4	"	79.1	56.0	7.685	
341†	"	54.9	"	55.2	56.3	6.261	
510†	"	118.8	"	120.3	42.8	9.450	
511†	"	75.1	"	76.1	42.1	7.229	
512†	"	41.8	"	42.2	45.0	5.201	
513†	"	177.7	"	180.3	46.5	12.03	
514†	"	168.6	"	171.7	37 7	11.415	
515†	"	137.0	"	138.1	37.6	10.101	
516†	"	110.8	"	112.0	37.3	8.951	
517†	"	86.2	"	87.2	37.5	7.751	
518†	"	55.6	"	56.0	37.8	6.015	Air, 68.5°.
519†	"	27.3	"	27.5	37.9	4.001	

TABLE No. 4—(*Continued*).

BRASS PIPE *VIII.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
57	*C–D*	49.55	.....	.....	69.4°	7.443 }	†Heads read in mercury.
58	"	40.30	.....	.....	69.4	6.622 } For *C–D*.	*Columns vibrating badly.
59	"	32.64	*A–B*	33.49	69.4	5.833 }	5.895 }
60	"	20.59	"	21.25	69.4	4.501 }	4.549 }
61	"	11.96*	"	12.31*	69.4	3.300 }	3.335 } Velocities for *A–B*.
62	"	4.40	"	4.54	69.4	1.850 }	1.870 }
63	"	1.38	"	1.50	69.4	0.947 }	0.957 }
172	*B–C*	43.96	.....	.....	67.5	6.941	
173	"	29.05	.....	.....	67.5	5.584	
174	"	17.63	.....	.....	69.0	4.117	
175	"	10.51	.....	.....	69.3	3.013	
168†	*A–B*	45.23	*B–D*	44.05	67.5	7.015 }	
169†	"	30.81	"	30.09	67.5	5.644 } For	Velocities for *B–D* same as for
170†	"	17.58	"	17.49	69.0	4.161 } *C–D*.	*B–C*. Experiments 172 to 175.
171†	"	10.52	"	10.58	69.3	3.016 }	
279†	*C–D*	44.86	.....	.....	66.1	6.956	
280†	"	29.91	.....	.....	65.0	5.513	
281†	"	20.85	.....	.....	65.0	4.439	
282†	"	12.43	.....	.....	65.0	3.288	
379†	"	44.2	.....	.....	53.0	6.691	
394	"	30.66	.....	.....	51.5	5.389	
395	"	22.78	.....	.....	52.2	4.553	
396	"	15.07	.....	.....	52.2	3.584	Air, 67°.
397	"	6.18	.....	.....	53.3	2.150	
398	"	6.55	.....	.....	54.6	2.216	
556†	*A–B*	183.1	.....	.....	71	14.97	
557†	"	194.9	.....	.....	37	14.545	
558†	"	160.7	.....	.....	36.7	13.08	
559†	"	134.3	.....	.....	36	11.77	
560†	"	103.4	.....	.....	36	10.15	
561†	"	81.3	.....	.....	36.1	8.791	Air, 66°.
562†	"	58.6	.....	.....	36.1	7.370	
563†	"	38.5	.....	.....	36.3	5.770	
564†	"	23.4	.....	.....	36.5	4.332	
565†	"	134.6	.....	.....	39.2	11.87	
566†	"	114.6	.....	.....	48.8	10.99	
567†	"	80.8	.....	.....	48.4	9.063	
568†	"	54.0	.....	.....	49.0	7.252	
569†	"	26.5	.....	.....	49.2	4.824	Air, 66°.

Brass Pipe *XI.*

80	*A–B*	43.99			69.0°	4.567	†Heads read in mercury.
81	"	29.37			69.0	3.626	
82	"	18.91			69.0	2.813	
83	"	11.55			69.0	2.127	
84	"	4.19			69.0	1.375	
133†	"	69.44	*B–C*	70.76	67.8	5.953	
134†	"	56.29	"	57.52	67.8	5.271	
135†	"	46.15	"	46.99	67.6	4.704	
136†	"	37.35	"	38.30	69.0	4.182	
137†	"	25.98	"	26.72	69.7	3.409	
138†	"	15.05	"	15.66	70.0	2.517	
139†	"	8.70	"	9.08	70.0	1.832	
372†	"	135.1	"	137.9	69.0	8.741	In 372 and 373 the discharge valve remained in the same position. They show the temperature effect on the discharge very clearly.
373†	"	135.3	"	138.2	56.5	8.497	
374†	"	206.4	"	210.8	57.5	10.872	
375†	"	173.9	"	177.7	58.0	9.854	
376†	"	103.3	"	105.3	55.3	7.261	
377†	"	66.8	"	68.1	55.8	5.651	
378†	"	32.1	"	32.9	56.3	3.726	
479†	"	198.3	"	201.4	37.9	10.077	Pipe *XIII* removed, 372 to 492.
480†	"	158.7	"	161.4	37.8	8.918	Air, 67°.
481†	"	124.2	"	126.2	37.0	7.685	
482†	"	92.3	"	93.9	37.0	6.513	
483†	"	57.9	"	58.8	37.1	4.975	
484†	"	19.1	"	19.4	37.4	2.714	Air, 66°.
485†	"	197.4	"	201.2	47.6	10.386	
486†	"	130.1	"	132.8	49.1	8.238	
487†	"	198.5	"	201.9	39.1	10.170	Air, 69°.
488†	"	198.4	"	201.8	41.1	10.206	
489†	"	199.0	"	202.6	43.9	10.266	
490†	"	283.5			48.5	12.751	Section *B–C* removed.
491†	"	286.5			39.9	12.534	
492†	"	233.1			43.0	11.348	

TABLE No. 4—(*Continued*).

BRASS PIPE *X*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
71	*A-B*	48.38	.....	.....	70.3	5.311	† Head read in mercury.
72	"	33.20	.....	.....	70.6	4.278	
73	"	21.19	.....	.....	70.7	3.301	
74	"	9.28	.....	.....	71.0	2.056	
75	"	2.59	.....	.....	71.0	1.107	
147†	"	76.72	*B-C*	76.77	68.3	6.914	
148†	"	59.75	"	59.78	68.0	5.972	
149†	"	40.00	"	40.16	68.0	4.772	
150†	"	29.57	"	29.75	68.0	3.895	
151†	"	17.06	"	16.55	68.1	2.939	
152†	"	11.17	"	11.54	68.3	2.333	
153†	"	3.93	"	3.95	68.7	1.335	
354†	"	51.05	"	51.09	68.1	5.483	
355†	"	50.99	"	50.95	56.6	5.340	
356†	"	78.43	"	78.31	54.0	6.796	
357†	"	40.44	"	40.56	56.2	4.681	
358†	"	15.93	"	16.00	55.2	2.749	
529†	"	181.9	"	181.4	64.8	11.321	
530†	"	148.2	"	147.8	55.2	9.823	
531†	"	114.6	"	114.3	51.0	8.411	
532†	"	180.0	"	178.7	74.1	11.387	
533†	"	139.1	"	137.8	73.4	9.818	
534†	"	173.9	"	173.9	42.5	10.462	
535†	"	145.0	"	145.2	42.0	9.385	
536†	"	110.2	"	110.6	44.0	8.057	
537†	"	74.6	"	75.0	45.2	6.450	
538†	"	171.7	"	171.3	38.0	10.276	
539†	"	127.6	"	127.8	37.1	8.636	
540†	"	92.6	"	93.0	37.2	7.182	
541†	"	56.4	"	56.5	37.2	5.388	
542†	"	32.8	"	32.7	37.1	3.970	
543†	"	149.4	"	149.0	36.7	9.445	

BRASS PIPE *XIII.*

85	*A–B*	49.61			69.6°	4.115	†Heads read in mercury.
86	"	33.48			69.6	3.294	*Columns vibrating badly; vibrations greater in 293 than in 294; critical-velocity region.
87	"	17.21			69.6	2.250	
88	"	5.60			69.6	1.332	
140†	"	217.4	*B–C*	218.1	67.8	9.635	
141†	"	176.6	"	177.2	67.8	8.531	
142†	"	144.3	"	144.8	68.6	7.615	
143†	"	117.5	"	117.5	69.0	6.658	
144†	"	82.0	"	82.4	69.7	5.426	
145†	"	48.3	"	48.6	70.0	4.007	
146†	"	27.9	"	28.0	70.0	2.917	
293	"	7.11*	"	7.99*	60.6	1.765	
294	"	5.99*	"	6.56*	61.0	1.215	
295	"	4.47	"	4.47	61.5	1.270	
296	"	3.13	"	3.15	62.0	0.898	
297	"	1.85	"	1.87	62.1	0.540	
298	"	0.91	"	0.84	62.4	0.267	
319†	"	220.3	"	220.3	65.2	9.378	
320†	"	143.2	"	144.1	65.2	7.507	
321†	"	76.6	"	77.3	65.2	5.231	
330†	"	137.6	"	138.4	56.5	7.229	
331†	"	83.8	"	84.5	56.5	5.418	Air, 70°.
332†	"	192.5	"	193.5	56.5	8.775	
493†	"	406.7			63.2	13.651	
494†	"	300.3			60.8	11.43	
495†	"	408.3			46.2	13.20	Air, 67°. Removed *XI*, except entry length and piezometer *A*. End length of *XI*, with reducer, screwed into *A*. *XIII* *B–C* removed.
496†	"	353.7			48.6	12.22	
497†	"	282.4			47.4	10.71	
498†	"	213.2			46.8	9.097	
499†	"	209.2			38.2	8 777	
500†	"	302.5			36.3	10.780	
501†	"	402.5			37.4	12.78	
502†	"	252.9	*B–C*	253.6	50.0	10.07	*B–C* put on.
503†	"	199.7	"	201.2	50.0	8.836	
504†	"	124.3	"	125.1	47.0	6.664	
505†	"	81.7	"	82.0	46.0	5.227	
506†	"	26.4	"	27.2	39.0	2.744	
507†	"	64.0	"	63.9	38.8	4.443	Air, 65°.
508†	"	112.7	"	114.0	38.5	6.182	
509†	"	155.9	"	158.4	38.9	7.468	

TABLE No. 4—(*Continued*).

BRASS PIPE *XII.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.		Remarks.
76	*A–B*	55.18			72.0°	4.940		†Heads read in mercury.
77	"	39.17			72.3	4.002		
78	"	21.32			72.4	2.865		
79	"	9.53			72.5	1.809		
154†	"	205.9	*B–D*	187.8	68.3	10.477	10.165	
155†	"	160.4	"	146.3	68.0	9.050	8.780	
156†	"	107.7	"	98.64	68.0	7.232	7.016	
157†	"	80.08	"	73.15	68.0	5.903	5.727	
158†	"	46.63	"	42.56	68.1	4.454	4.321	
159†	"	31.16	"	28.41	68.3	3.536	3.430	
160†	"	11.74	"	10.47	68.7	2.023	1.963	
						For *A–B*	For *B–D*	
						For *C–D*		
161			*B–C*	185.6	68.3	10.165		Experiments 161 to 167 were simultaneous with 154 to 160. The heads were read on a water gauge. The heads given for *B–D* (154 to 160) are really for *C–D*, the *B–C* heads (161 to 167) having been subtracted.
162			"	144.8	68.0	8.780		
163			"	97.4	68.0	7.016		
164			"	72.32	68.0	5.727		
165			"	42.27	68.1	4.321		
166			"	28.15	68.3	3.430		
167			"	10.52	68.7	1.963		
267†	*A–B*	135.4	*C–D*	124.2	68.8	8.270	8.024	
268†	"	73.22	"	67.4	69.2	5.817	5.644	
269†	"	133.0	"	122.2	65.0	8.137	7.895	
270†	"	104.4	"	95.94	65.0	7.088	6.877	
271†	"	64.35	"	59.34	65.0	5.362	5.203	
272†	"	48.35	"	44.59	65.0	4.556	4.422	
273†	"	28.92	"	26.61	65.0	3.390	3.290	
274†	"	207.2	"	190.2	65.3	10.510	10.197	
						For *A–B*	For *C–D*	
352†			"	125.2	68.1		8.061	
353†			"	125.0	56.6		7.850	Air, 68°.
359†			"	192.6	54.0		10.004	
360†			"	156.7	55.1		8.910	
361†			"	82.8	55.0		6.172	Air, 67°.
362†			"	34.6	56.0		3.738	
520†	*A–B*	202.7	"	186.1	45.4	9.907	9.612	
521†	"	145.8	"	133.4	45.4	8.170	7.927	
522†	"	81.2	"	74.2	45.7	5.843	5.669	
						For *A–B*	For *C–D*	
523†	"	288.7			54.9	12.425		*B–D* removed.
524†	"	249.5			53.0	11.375		Air, 71.5°.
525†	"	235.1			39.0	10.609		
526†	"	288.1			39.4	11.910		
527†	"	243.5			43.0	10.950		
528†	"	290.0			45.6	12.175		

BRASS PIPE *XV.*

94	*A–B*	44.58	.....	.....	70.6°	2.892	†Heads read in mercury.
95	"	33.83	.....	.....	70.6	2.596	
96	"	19.26	.....	.....	70.6	2.362	
97	"	8.623	.....	.....	70.0	1.248	
98	"	2.001	.....	.....	70.0	0.300	
117†	"	180.2	*B–C*	194.2	69.5	6.761	
118†	"	155.4	"	167.6	70.0	5.946	
119†	"	129.6	"	139.5	70.0	5.384	
120†	"	99.9	"	107.6	70.2	4.630	
121†	"	67.84	"	72.47	70.4	3.730	
122†	"	13.60	"	20.72	70.9	1.953	
123†	"	275.8	"	299.3	70.6	8.304	
124†	"	218.4	"	235.6	71.0	7.249	
222†	"	510.5	.....	.....	74.8	11.868	*B–C* removed.
223†	"	411.4	.....	.....	75.5	10.519	
224†	"	319.1	.....	.....	76.0	9.102	
225†	"	207.7	.....	.....	75.7	7.109	
226†	"	114.2	.....	.....	75.1	5.075	
227†	"	45.32	.....	.....	73.9	3.009	
228†	"	29.05	.....	.....	73.1	2.394	
229†	"	18.16	.....	.....	73.0	1.952	
230†	"	9.33	.....	.....	73.1	1.362	
237†	"	278.4	*B–C*	303.3	72.9	8.398	
238†	"	179.2	"	194.5	70.9	6.537	
239†	"	122.7	"	133.7	73.6	5.277	
240†	"	273.4	"	298.4	70.7	8.217	Pipes Nos. 2 and 3 interchanged, placing Section *B–C* up stream.
241†	"	233.5	"	255.4	70.8	7.575	
242†	"	151.4	"	164.6	71.0	5.902	
253†	"	281.9	"	294.1	70.2	8.489	Pipes cleaned. *A–B* up stream.
254†	"	227.5	"	228.0	70.3	7.500	
255†	"	145.4	"	146.2	70.4	5.852	
256†	"	52.55	"	52.66	70.7	3.276	
257†	"	32.58	"	33.84	71.7	2.537	
258†	"	11.41	"	11.53	72.9	1.767	
368†	"	174.4	"	175.2	53.7	6.257	
369†	"	242.0	"	243.0	55.0	7.578	
370†	"	292.2	"	293.4	55.4	8.460	
371†	"	102.2	"	102.6	56.0	4.682	
413†	"	270.1	"	271.0	46.0	7.800	
414†	"	176.2	"	177.1	47.5	6.145	
415†	"	175.7	"	176.8	47.0	6.188	Air, 68°.
416†	"	109.8	"	110.4	49.6	4.781	
417†	"	52.3	"	53.0	45.7	3.183	Air, 69.5°.

TABLE No. 4—(*Continued*).

BRASS PIPE *XIV.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
246†	*A-B*	304.0	*B-C*	308.8	70.2°	9.957	NOTE: Experiments 89 to 93, 125 to 132, 231 to 236, were rejected. The results on the two sections were not consistent, and when the pipe was taken down the ends were found to be jammed. (This pipe is very thin.) The jammed ends were cut off, and the pipes were refaced and rethreaded. Subsequent examinations showed no trouble.
247†	"	236.3	"	240.6	70.3	8.618	
248†	"	154.1	"	157.1	70.4	6.685	
249†	"	97.16	"	98.73	70.7	5.179	
250†	"	54.49	"	55.05	71.7	3.722	
251†	"	28.92	"	29.28	72.9	2.608	
252†	"	12.49	"	13.80	73.5	1.743	
363†	"	203.0	"	206 4	54.8	7.661	
364†	"	151.7	"	154.5	56.0	6.483	
365†	"	89.6	"	91.5	56.4	4.813	
366†	"	39.0	"	39.8	56.8	2.943	Air, 67.5°.
367†	"	310.5	"	317.1	54.1	9.760	
447†	"	202.0	"	204.7	47.2	7.427	Air, 76°.
448†	"	163.3	"	166.0	44.4	6.548	
449†	"	134.4	"	136.4	45.8	5.870	Air, 68.5°.
450†	"	96.4	"	97.9	42.4	4.859	
451†	"	61.5	"	62.2	42.8	3.780	
452†	"	35.7	"	36.6	42.2	2.825	Air, 66.5°.
453†	"	302.3	"	306.8	42.2	9.314	
454†	"	256.4	"	260.2	49.4	8.584	
455†	"	571.3	.....	.....	61.4	14.011	
456†	"	479.7	.....	.....	59.8	12.659	Air, 72°.
457†	"	373.1	.....	.....	59.8	10.936	
458†	"	266.8	.....	.....	60.8	9.047	
459†	"	265.3	.....	.....	42.5	8.625	Air, 71°.
460†	"	359.0	.....	.....	45.0	10.333	
461†	"	442.6	.....	.....	47.9	11.772	
462†	"	565.7	.....	.....	48.8	13.566	Air, 74°.
463†	"	555.7	.....	.....	37.8	13.036	Air, 68°.
464†	"	517.3	.....	.....	38.8	12.567	
465†	"	429.5	.....	.....	38.0	11.270	
466†	"	324.4	.....	.....	37.5	9.569	Air, 65.8°.
467†	"	216.5	.....	.....	37.6	7.553	
468†	"	93.3	.....	.....	37.6	4.792	Air, 65°.

†Heads read in mercury.

BRASS PIPE *XV.*

Brass Pipe *XVI.*

99	*A–B*	44.46			67.7*	2.676	† Heads read in mercury.
100	"	28.59			68.0	2.074	* Sudden change in gauge columns, probably due to the settling of the valve.
101	"	18.29			69.0	1.378	
102	"	7.804			69.5	0.602	
103†	"	178.6	*B–C*	178.4	70	5.135	
104†	"	136.7	"	136.6	70.2	4.424	
105†	"	105.4	"	105.2	70.9	3.840	
106†	"	76.4	"	76.6	71.0	3.230	
107†	"	48.29	"	48.6	71.2	2.721	
108†	"	24.15	"	23.0	71.9	1.790	
109†	"	60.61	"	62.36	69.5	2.917	
110†	"	56.53	"	58.49	70.0	2.866	
111†	"	37.36	"	38.42	70.0	2.559	
112†	"	31.94	"	31.93	70.2	2.309	
113†	"	11.72	"	11.71	70.4	0.911	
114†	"	5.86	"	5.97	70.9	0.451	
115†	"	271.4	"	276.6	70.6	6.542	
116†	"	229.9	"	234.7	71.0	5.993	
213†	"	512.8			74.5	9.448	*B–C* removed.
214†	"	423.0			75.0	8.467	
215†	"	323.9			75.1	7.277	
216†	"	231.1			75.2	6.001	
217†	"	124.6			75.3	4.255	
218†	"	47.25			75.1	2.020	
219†	"	32.24			75.1	2·282	
220†	"	19.89			75.1	1.614	
221†	"	8.97			75.2	0.730	
243†	"	276.6	*B–C*	280.5	70.7	6.606	Pipes Nos. 2 and 3 interchanged, placing section *B–C* up stream.
244†	"	227.0	"	230.2	70.8	5.816	
245†	"	136.2	"	137.9	71.0	4.437	
314†	"	178.0	"	180.7	64.3	5.107	Section *A–B* up stream.
315†	"	129.3	"	131.6	64.5	4.298	
316†	"	76.47	"	80.14	64.8	3.248	
317†	"	39.12	"	37.27	65.0	2.523	
318†	"	284.2	"	288.2	65.0	6.645	
322†	"	521.1	"		64.0	9.337	*B–C* removed.
323†	"	446.1			64.0	8.552	
324†	"	324.5			64.0	7.143	
333†	"	496.8			55.0	8.940	
334†	"	388.2			55.8	7.809	

TABLE No. 4—(*Continued*).

BRASS PIPE *XV*—(*Continued*).

No. of Exp't.	Section.	Loss of Head, in water. Feet per 100.	Section.	Loss of Head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
418†	*A–B*	287.8			44.1	8.168	
419†	"	443.9			43.2	9.991	No. 419 seems erratic. No. 443 taken as a check.
420†	"	364.3*			46.4	9.254	*In No. 420 the head decreased by jumps, probably due to the valve settling slightly.
421†	"	440.7			38.2	10.237	
422†	"	374.3			38.0	9.327	
423†	"	314.1			37.7	8.450	
424†	"	255.7			37.6	7.522	Air, 69°.
425†	"	194.3			37.6	6.444	
426†	"	132.6			37.5	5.194	Air, 66°.
427†	"	71.4			37.6	3.752	
443†	"	440			43.7	10.344	
444†	"	461.4			45.8	10.695	
445†	"	408.7			46.2	9.965	
446†	"	325.9			46.1	8.759	Air, 71°.

TABLE No. 4—(*Continued*).

BRASS PIPE *XVI*—(*Continued*).

No. of Exp't.	Section.	Loss of Head, in water. Feet per 100.	Section.	Loss of Head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
335†	*A-B*	267.0*	.....	.....	56.5	6.327	Air, 62°.
336†	"	250.8	.....	.....	57.0	6.130	
337†	"	110.1	.....	.....	57.4	3.870	
428†	"	496.8	.....	.....	43.5	8.746	
429†	"	409.3	.....	.....	45.0	7.869	
430†	"	307.8	.....	.....	47.8	6.754	Air, 78°.
431†	"	307.4	.....	.....	39.4	6.659	
432†	"	389.9	.....	.....	38	7.562	
433†	"	436.2	.....	.....	38.3	8.047	
434†	"	481.0	.....	.....	38.6	8.516	
435†	"	267.9	*B-C*	271.1	39.0	6.140	Air, 65°.
436†	"	213.5	"	216.6	39.0	5.424	
437†	"	158.7	"	162.6	38.6	4.751	
438†	"	103.2	"	101.3	38.5	4.071	Air, 68°.
439†	"	66.7	"	64.9	38.5	3.142	
440†	"	33.7	"	33.0	38.5	1.635	
441†	"	19.1	"	18.8	38.4	0.958	
442†	"	7.2	"	7.2	38.3	0.387	

TABLE No. 5.—GALVANIZED PIPE *XVII.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
592	70.89	35.5°	10.036	All heads measured in mercury.
593	39.90	35.8	7.493	
594	54.00	44.4	8.762	
595	39.59	42.5	7.452	Air, 64°.
596	25.85	41.2	6.008	
597	13.17	40.9	4.229	
598	5.88	41.2	2.795	
599	62.46	35.5	9.374	
600	55.35	35.6	8.476	
601	28.75	35.6	6.340	
602	16.51	36.4	4.766	
620	44.19	59.5	7.955	
621	26.21	51.2	6.092	
741	44.87	79	8.375	Experimental pipe reversed (Piezometer *B* up stream) for these experiments.
742	43.89	43.6	7.813	
743	43.67	35.6	7.711	
744	74.36	35.4	10.155	
745	73.74	35.2	10.118	
746	55.61	35.5	8.860	
747	26.82	35.2	6.041	
748	13.21	35.4	4.216	
749	7.37	35.6	3.111	

GALVANIZED PIPE *XVIII.*

631	51.61	44.6°	9.469	All heads measured in mercury.
632	41.11	42.9	8.321	
633	30.06	42.4	7.060	
634	20.60	42.0	5.708	
635	10.40	42.5	3.913	
636	4.99	42.8	2.618	
637	75.83	36.0	11.470	
638	64.87	36.0	10.554	
639	50.87	71.5	9.635	
640	32.41	64	7.548	
641	74.37	39.8	11.427	
642	74.89	35.8	11.405	
643	50.10	36.1	9.159	
644	35.74	36.2	7.757	
645	19.99	35.8	5.513	
646	8.47	36.5	3.423	
737	51.74	37	9.271	Experimental pipe reversed (Piezometer *B* up stream) for these experiments.
738	31.00	37.2	7.047	
739	15.52	38.2	4.811	
740	71.22	35.1	10.916	

TABLE No. 5—*Continued.*—GALVANIZED PIPE *XIX.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
622	96.62	55.0°	10.223	All heads measured in mercury.
623	61 20	49	7.909	
624	33.62	48	5.747	
625	16.72	48.2	3.894	
626	7.36	49.2	2.460	
627	143.31	77	12.783	
628	144.72	37.5	12.339	
629	80.22	37.5	9.049	
630	37.70	37.7	5.996	
755	98.04	78	9.994*	
756	97.56	50	10.079	
757	97.70	50.7	10.248	Experimental pipe reversed for these experiments.
758	78.17	52.0	9.028	
759	78.13	49.0	9.011	
760	39.71	48.5	6.267	
761	22.81	49.0	4.610	* Error in time? Velocity may be 10.316. See Experiment 768.
762	148.47	48.6	12.560	
763	149.69	37.1	12.578	
768	98.16	77.2	10.298	
769	77.00	80.2	9.196	
770	77.88	45.9	8.931	
771	97.65	45.8	10.062	

GALVANIZED PIPE *XX.*

603	166.6	61.5	10.885	All heads measured in mercury.
604	109.1	58.8	8.725	
605	165.6	37.2	10.653	
606	149.6	36.8	10.145	
607	116.5	35.9	8.877	
608	79.15	35.5	7.240	
609	46.20	35.6	5.499	
610	21.12	35.8	3.634	
611	10.34	39.0	2.487	
612	5.03	40.6	1.669	
613	113.3	42.6	8.781	
614	91.35	49.5	7.877	
615	112.6	47.0	8.775	
616	59.93	46.4	6.308	
617	112.2	77.2	8.896	
618	51.56	78.3	5.965	
619	164.5	79.2	10.884	
764	166.4	48.4	10.744	Experimental pipe reversed for these experiments.
765	108.2	45.2	8.607	
766	57.4	45.2	6.156	
767	25.9	52	4.077	

TABLE No. 5—*Continued.*—GALVANIZED PIPE *XXI.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity in feet per second.	Remarks.
570	408.5	71.5°	11.411	All heads measured in mercury.
571	205.1	71.5	8.009	
572	341.5	68	10.394	
573	257.2	54	8.956	
574	181.3	52.2	7.489	
575	125.6	59.2	6.219	
576	84.71	57.8	5.085	
577	53.77	57.1	4.039	
578	31.68	59.8	3.067	
579	374.9	38.5	10.763	
580	311.8	38.6	9.830	
581	258.4	37.4	8.988	
582	195.3	37.4	7.739	
583	133.8	37.5	6.394	
584	84.05	38.0	5.025	
585	47.50	38.4	3.756	
586	5.97	42.6	1.305	
587	11.94	44.0	1.856	
588	25.69	47.2	2.744	
589	268.1	46.3	9.112	
590	142.6	47.8	6.621	
591	388.3	49.7	10.992	
750	316.5	45.1	9.795	Experimental pipe reversed (Piezometer *B* up stream) for these experiments.
751	315.4	36.4	9.651	
752	244.5	38.9	8.464	
753	161.7	36.4	6.834	
754	77.7	39.0	4.731	

REDUCTION TO STANDARD TEMPERATURES.

Brass Pipes.—After a few experiments had been made on each pipe, a preliminary logarithmic plotting of the results showed that for each of the fifteen brass pipes the loss of head varied very nearly as the 1.75 power of the velocity. Advantage was taken of this fact to bring the results to chosen standard temperatures. Plates XXXVIII and XXXIX were drawn, using heads in feet per 100 ft. as ordinates and the values of $V^{1.75}$ as abscissas. For any particular pipe on these plates, it will be noticed that there is a gradual increase in the ordinate as the temperature of the water drops, and that points of about the same temperature lie approximately on a straight line. Such lines were drawn for standard temperatures of 70, 55 and 40° Fahr. The difference in ordinates between two lines, divided by the ordinate, gives the ratio or percentage of increase or decrease in the loss of head for a change of temperature of 15 degrees. The percentage is always less for 40° than for 55°, as the ordinate itself is greater. In those cases in which the distances between the lines were different, thus resulting in two different percentages at 55°, the average of these

two percentages was taken. The three percentages reduced to percentages per 10°, instead of 15°, were then plotted as ordinates, with temperatures as abscissas, and a smooth curve was drawn through the three points. The percentage correction per 10° for any observed temperature was read from these curves. The diagram used is shown in Fig. 3, in which it will be seen that for all pipes the correction factor is about 4 per cent. Another diagram was therefore constructed, from which the 4% corrections of the different heads for any temperature interval could be read, and the correction desired was then obtained by the slide-rule.

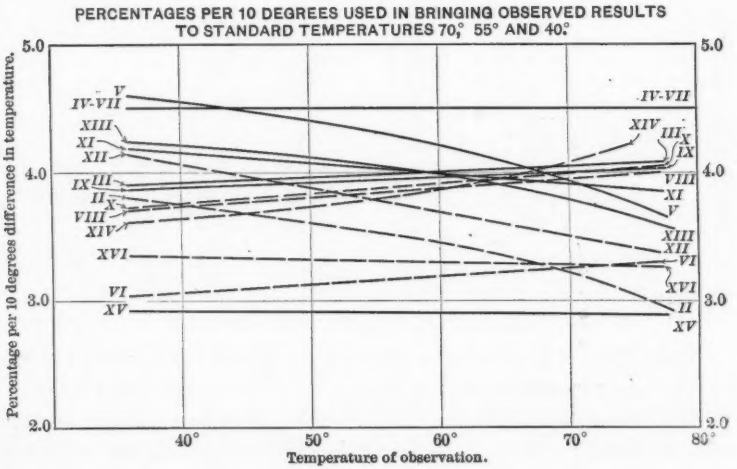
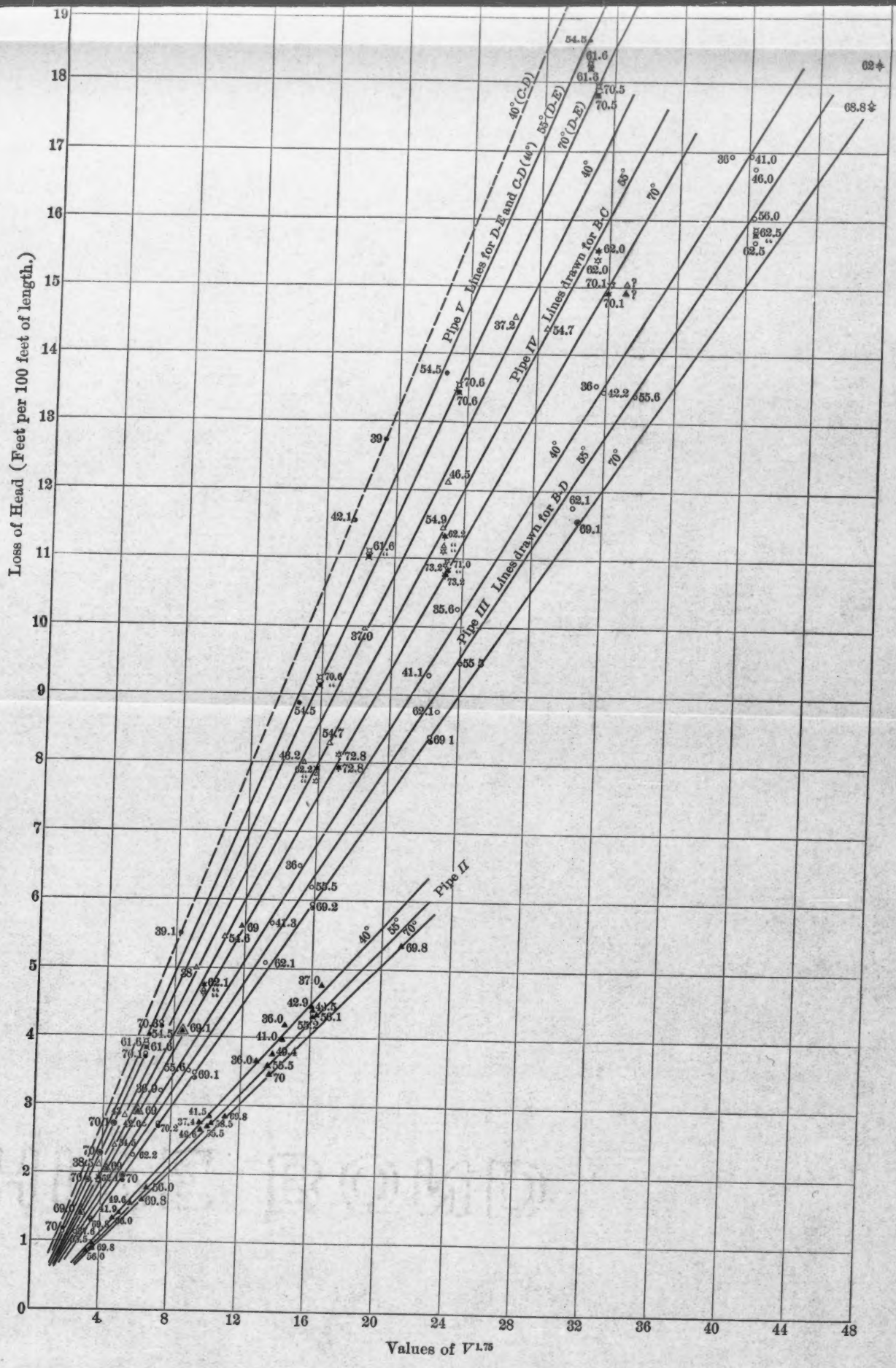


FIG. 3.

In Fig. 3 it will be noticed that for some pipes the percentage curves slope downward for increasing temperatures, and for other pipes there is an opposite tendency. While it is not to be maintained that these corrections are accurate, it is believed that they are correct within several tenths of 1 per cent. If this is true, a profile view of Fig. 3, at 70°, 55° or 40°, made by taking the percentages and plotting them with respect to the pipe diameters, gives indications of a sinuous relation between the temperature effects and the diameters. The evidence, however, is not conclusive enough to justify the statement that this is a fact.

Aside from errors in judgment in drawing the lines on Plates XXXVIII and XXXIX, there is at least one way in which small errors


Loss of Head (Feet per 100 feet of length.)
Values of $V^{1.75}$
Pipe V Lines for D-E and C-D (40°) 55°(D-E) 70°(D-E) 40°(C-D)
Pipe IV Lines drawn for B-C 40° 55° 70°
Pipe III Lines drawn for B-D 40° 55° 70°
Pipe II 40° 55° 70°

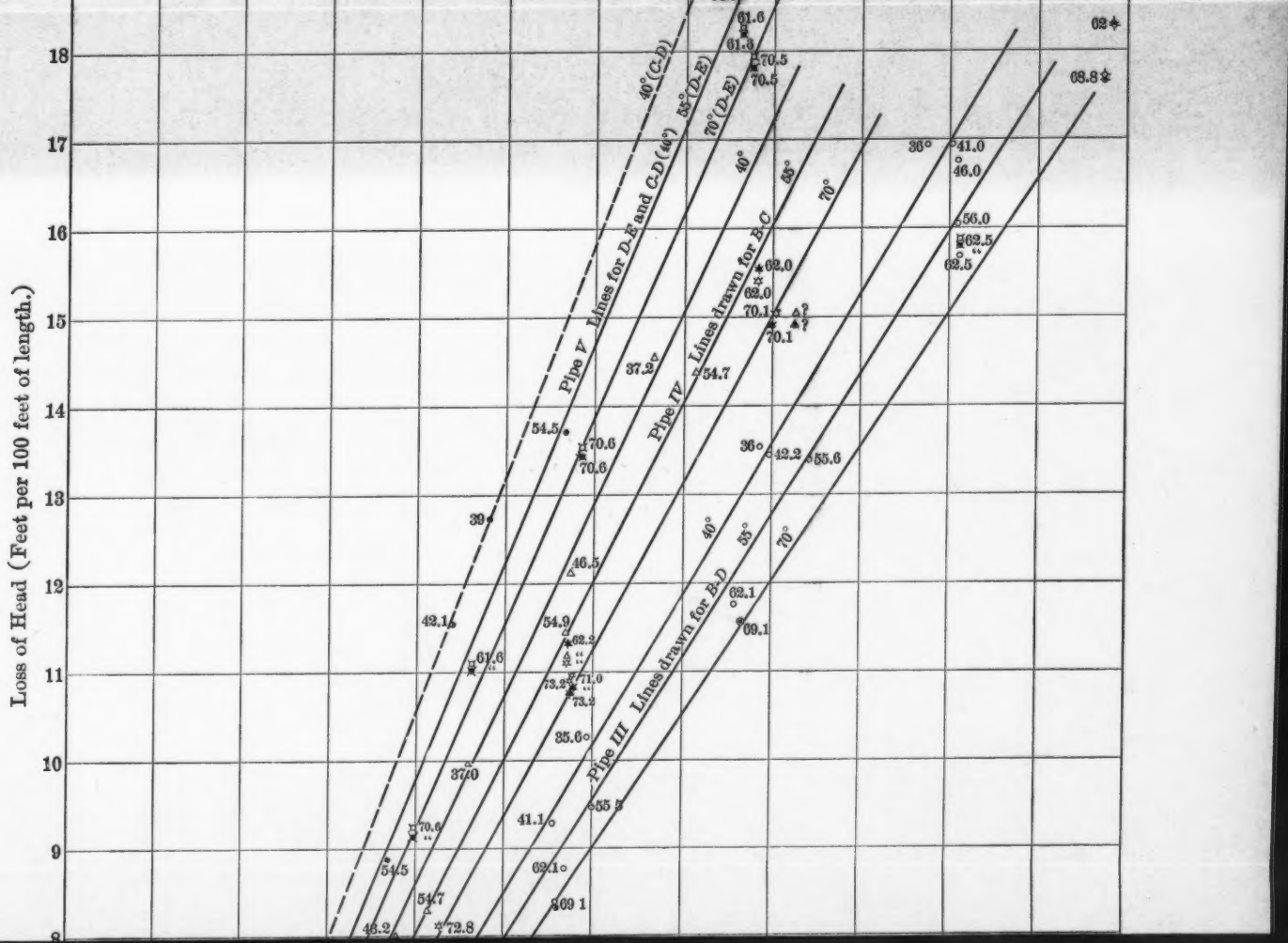
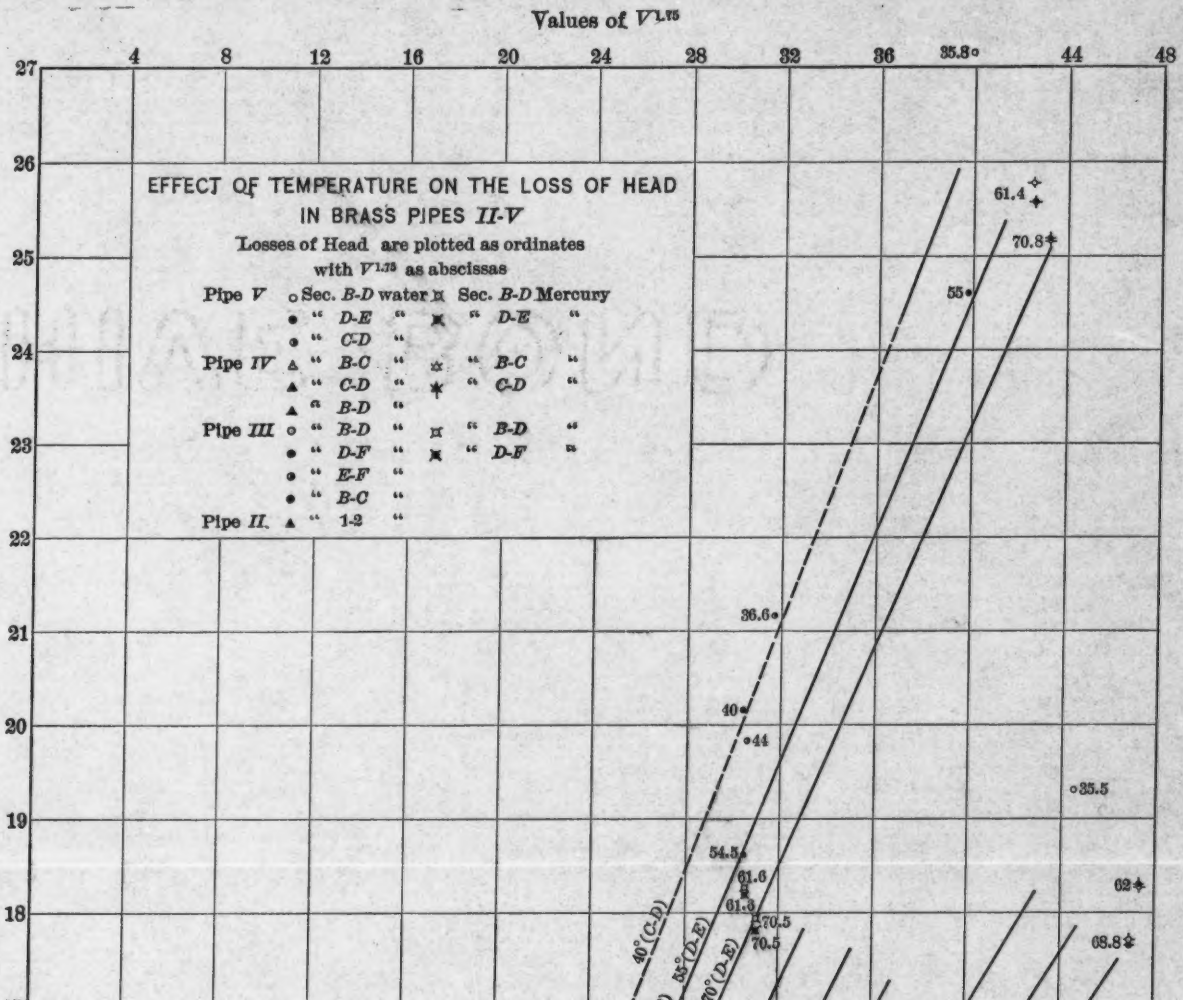

Loss of Head (Feet per 100 feet of length.)
18
17
16
15
14
13
12
11
10
9
8
Pipe V Lines for D-E and C-D (40°)
40°(C-D)
55°(D-E)
70°(D-E)
Pipe IV Lines drawn for B-C
40°
55°
70°
Pipe III Lines drawn for B-D
40°
55°
70°
61.6
61.3
70.5
70.5
62+
68.8
36°
41.0
46.0
56.0
62.5
62.5
62.0
62.0
70.1
70.1
37.2
54.7
54.5
70.6
70.6
36°
42.2
55.6
39
46.5
42.1
54.9
62.2
61.6
73.2
71.0
73.2
35.6
37.0
41.1
55.5
62.1
69.1
62.1
69.1
70.6
54.5
54.7
46.2
72.8

PLATE XXXVIII.
PAPERS, AM. SOC. C. E.
MAY, 1903.
SAPH AND SCHODER ON
FLOW OF WATER IN PIPES.



might be introduced into the reduction factor. It will be seen later, in the tables for m and n, that for the different standard temperatures there are slight differences in the value of n for a certain pipe, and sometimes quite decided differences between these values of n and the preliminary value, 1.75. The differences in the values of n would result in changing the relative position of the lines, as they are all drawn upon the basis of $n = 1.75$. The fact that n is sometimes different from 1.75 results in giving a slight curvature to the line passing through the points at a certain temperature. As stated, however, the errors are not large, and, taking into consideration the fact that the correction intervals were in almost all cases less than 10°, it is certain that the limits of error mentioned have not been exceeded. In addition, the corrections were usually made from both sides of the standard temperatures, and any appreciable error would be evident at once in the plotting.

Another method for getting the temperature correction consists in plotting the values of $m = \frac{H}{V^{1.75}}$ as ordinates, with the temperatures as abscissas. When this is done, a straight line results in some cases and a curve in others. It usually gives the same results as the method already presented, but, taken altogether, it is not as reliable.

Galvanized Pipes.—For the galvanized pipes, a diagram was made, as for the brass pipes, using for the abscissas those approximate powers of the velocity which a preliminary logarithmic plotting showed for each pipe. These powers or values of n were quite variable, as the following values show.

	n
Pipe *XVII*	1.95
" *XVIII*	1.82
" *XIX*	1.82
" *XX*	1.90
" *XXI*	1.95

The diagram, however, did not give such consistent results as did the diagrams for brass pipes. The experiments were mostly in the neighborhood of 40 degrees. The results were usually somewhat erratic, and in many cases the estimate had to be based on the assumption of a uniform change from 70 to 37 degrees. Upon passing to the final plotting, however, these estimates, which varied from 1 to 2%

for 10° difference in temperature, showed themselves to be in error. More consistent reduction factors were obtained by using large-scale logarithmic paper for a preliminary plotting. Upon Pipes *XVII* and *XXI* very little evidence of temperature effect could be found, and the results were not corrected. For Pipe *XIX* 1.5% for 10° was found to apply; and for Pipe *XX* 1.25% was used. For Pipe *XVIII* the results were changed by 5% in the neighborhood of 40°, but, from all appearances, this would be too large in the vicinity of 70 degrees. Pipe *XVIII*, however, seems to be exceptional, in several respects.

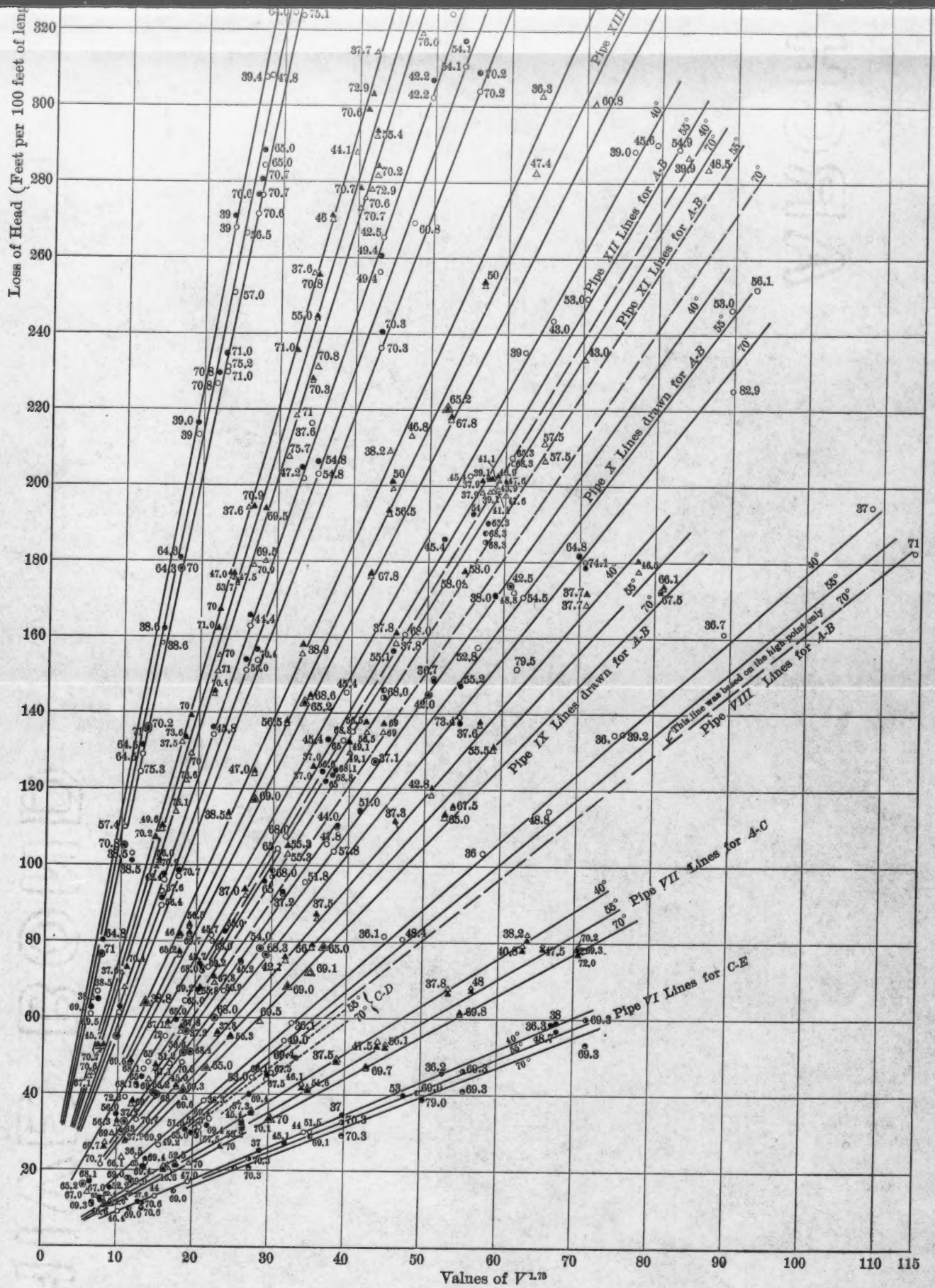
Logarithmic Plotting of Results.—After being brought to the standard temperatures the results were plotted on regular, 10-in. base, logarithmic, cross-section paper,* plotting losses of head as ordinates and velocities as abscissas. The use of such paper is now so common that no explanation is considered necessary.

This plotting is shown in Plate XL, which contains the results for both brass and galvanized pipes, plotted, however, for different origins. For the brass pipes, lines are drawn for the three standard temperatures, but for only one experimental section on each pipe, in order to avoid confusion.

Close inspection will show that in some instances the points do not lie exactly on the line. In such cases investigation was made to see if the reason existed in an error in the temperature reduction factor, but it was found that the differences were due to other causes. Sometimes the results obtained by mercury readings were slightly different from those taken in water. Altogether, however, the lines fit the points very well. Attention may be called here to the great uniformity in slope for the brass pipes.

Table No. 6 gives the values of m and n, as determined from the logarithmic plotting. In cases, however, where the points do not lie exactly on a straight line, or where, as in Pipe *XVI* at 40°, the points which determine the line are few in number, and for high velocities, there is usually a little uncertainty in drawing the line. In this way, small variations in m may be brought about, but when it is considered that there is a corresponding change in n, it will be seen that the two values taken together will represent the conditions quite accurately.

* The writers were supplied with this paper by John R. Freeman, M. Am. Soc. C. E., whose generosity and kindly interest they desire to acknowledge.


Loss of Head (Feet per 100 feet of leng
Values of $V^{1.75}$
Pipe VIII
Pipe XII Lines for A-B
Pipe XI Lines for A-B
Pipe X Lines drawn for A-B
Pipe IX Lines drawn for A-B
This line was based on the high-points only
Pipe VIII Lines for A-B
Pipe VII Lines for A-C
Pipe VI Lines for C-E
C-D
40°
55°
70°

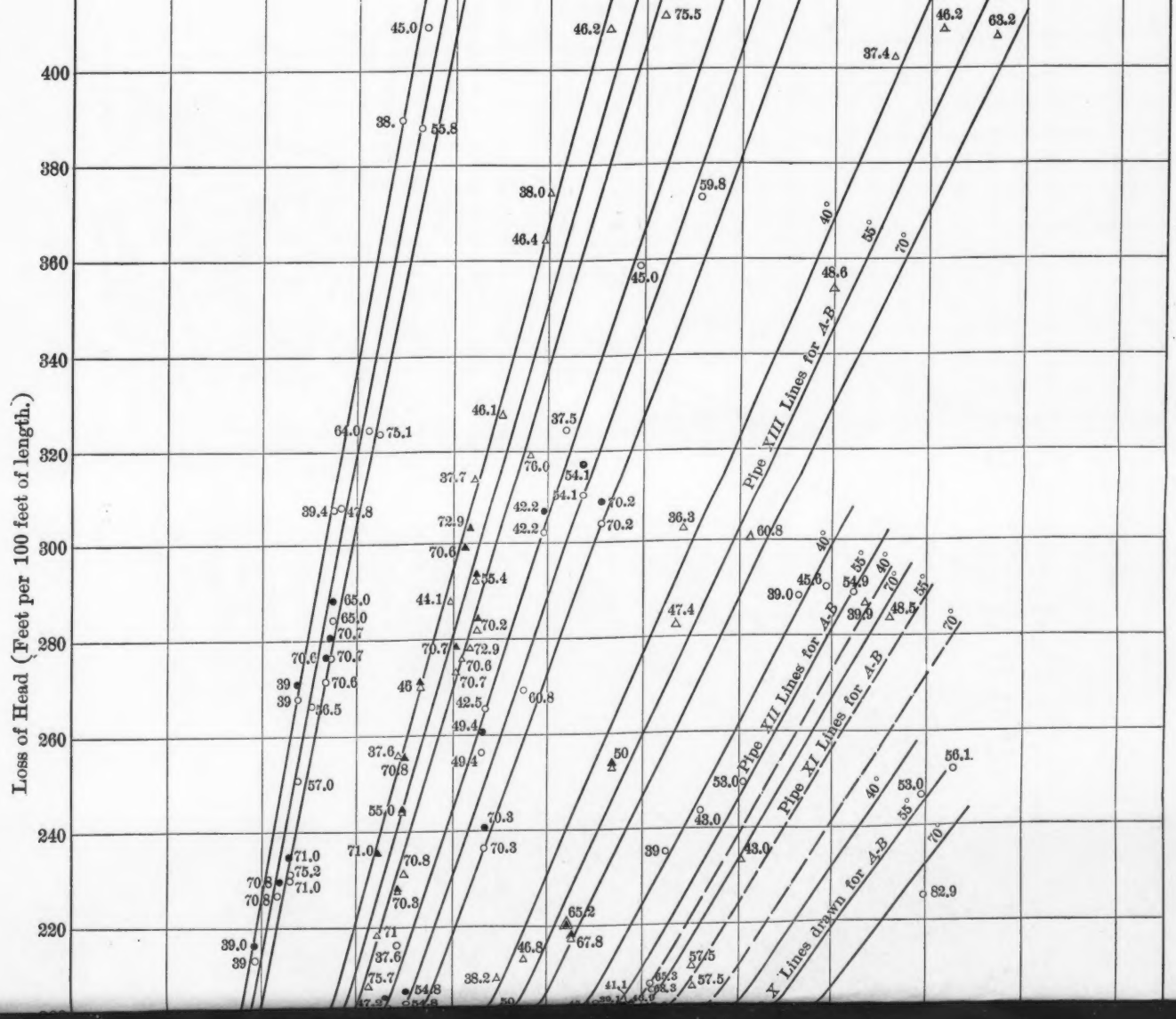
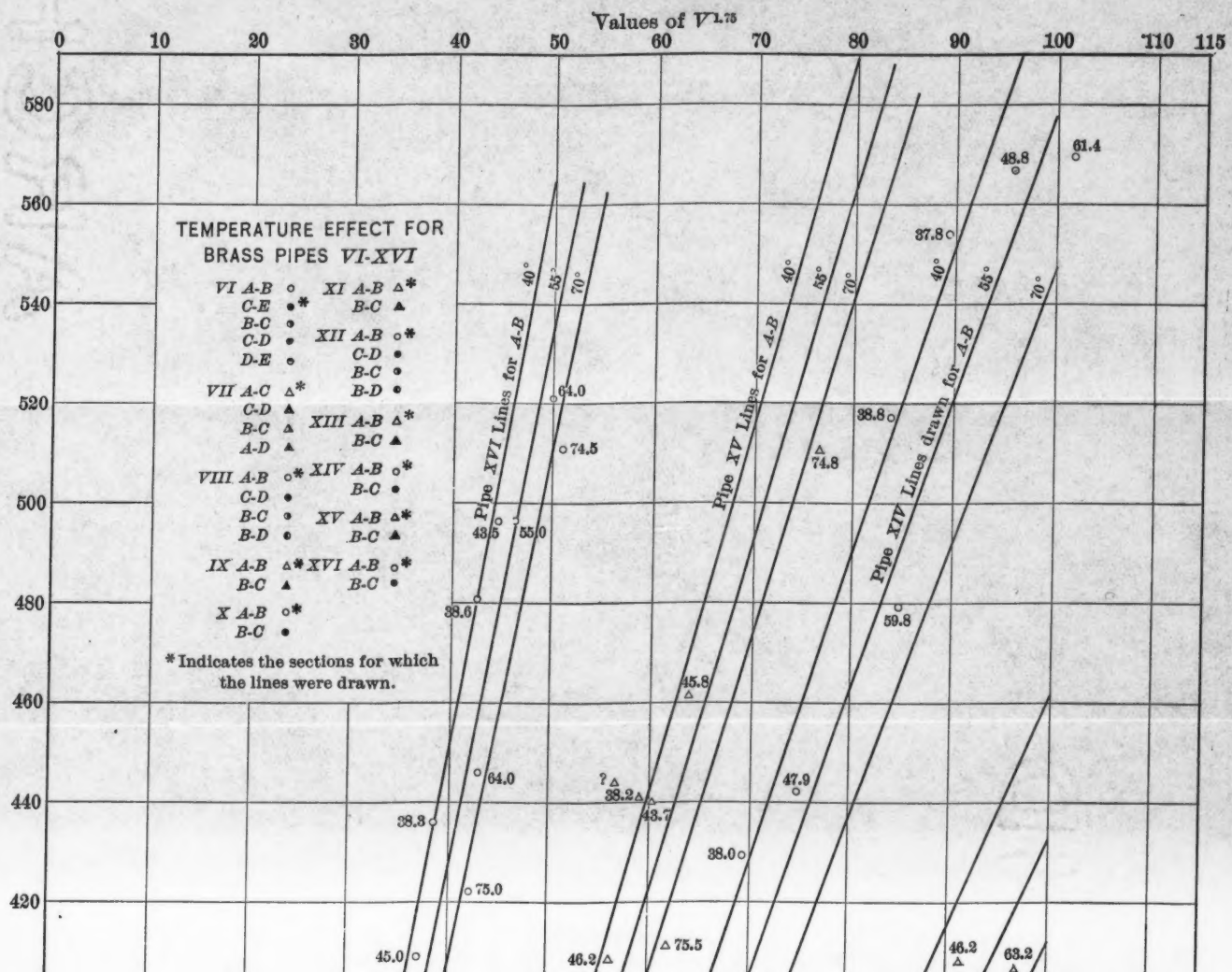

Loss of Head (Feet per 100 feet of length.)
400
380
360
340
320
300
280
260
240
220
Pipe XIII Lines for A-B
Pipe XII Lines for A-B
Pipe XI Lines for A-B
X Lines drawn for A-B
40°
55°
70°

PLATE XXXIX.
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In Table No. 6 there will also be found the values of m, as taken from Plates XXXVIII and XXXIX on which the points were plotted with heads as ordinates and the values of $V^{1.75}$ as abscissas. The slopes of the lines drawn must give the values of m corresponding to the power, 1.75, of the velocity. Upon comparing these values of m with those obtained from the logarithmic plotting, it is seen that they check quite well. These values of m are greater or less than the values determined logarithmically, accordingly as 1.75 is greater or less than the true n. Taken altogether, with these values of m, and $n = 1.75$, we can represent closely the whole series of experiments.

The method of least squares could also be applied in getting the values of m and n. This was tried in the case of Pipe *II*, and gave a close check upon the values taken from the logarithmic sheet. The method of least squares, however, is not as convenient, and does not expose the errors which may occur.

The differences in results for two sections of the same pipe do not seem to be accounted for through differences in diameter, except in Pipes *VI*, *VIII* and *XII*, where differences were known to exist and were allowed for in the calculations. In the other pipes small differences in resistance are noted, but must be accounted for otherwise. As first used, the two experimental sections of Pipe *XV* showed very discordant results, as the table and the logarithmic plotting show. After being cleaned by drawing waste cotton through, the results were more consistent. During the cleaning a small scale of brass was drawn out, and it seems very probable that the small differences noted in other pipes may be due to similar causes.

Table No. 7 gives the values of m and n for the galvanized pipes. As shown by the logarithmic plotting, Pipe *XVIII* seems to be an exceptional pipe. Even though of smaller diameter than Pipe *XVII* the losses of head, for velocities above 2.4 ft. per second, are lower than in Pipe *XVII* for the same velocity. It will be remembered, also, that Pipe *XVIII* is the one which showed high temperature effects in the neighborhood of 40°, and that it is the only one of the galvanized pipes which had been in use before the experiments. A slight, silt-like deposit which had occurred on the inner walls was entirely insufficient to relieve the roughness. Although the galvanized pipes do not seem to give such consistent results as the brass pipes, the experiments were made with the same care.

XIII	*B-C*	40	3.90	1.731	3.74		40	3.72	1.738
	B-D	70	3.95	1.739	.....				
	A-B	70	3.33	1.796	.....	*B-C*	70	4.25	1.733
		55	4.25	1.783	4.11		55	4.45	1.730
XIV	*A-B*	40	4.45	1.760	4.39		40	4.70	1.743
		70	4.70	1.743	4.61	*B-C*	70	5.32	1.755
		55	5.32	1.745	5.46		55	5.95	1.740
XV	*A-B*	40	5.90	1.747	5.78		40	6.45	1.731
		70	6.98	1.742	6.13	*A-B*	70	6.66	1.764
		55	6.96	1.774	6.76	*B-C*	70	7.12	1.765
		40	6.71	1.768	7.05				
	B-C	70	7.07	1.771	7.86				
		55	6.96	1.774	.....				
		40	6.71	1.768	.....				
XVI	*A-B*	70	7.07	1.771	10.21	*B-C*	70	9.23	1.785
		55	9.78	1.771	10.69		55	9.88	1.794
		40	10.13	1.780	11.95				
		70	10.98	1.795					

A-B and *B-C* in last columns before cleaning.

TABLE No. 6—Brass Pipes *II* to *XVI*, Inclusive.

Values of m and n. (m for Head in Feet per 100.)

Pipe.	Section.	Temp. Fahr.	m.	n.	m from $V^{1.75}$ diagrams.	Section.	Temp. Fahr.	m.	n.	
II		70°	0.252	1.749	0.253					
		55	0.267	1.748	0.268					
		40	0.282	1.750	0.282					
III	*B-D*	70	0.372	1.754	0.377	*D-F*	70°	0.375	1.750	
		55	0.386	1.767	0.400	*E-F*	70	0.357	1.776	Few points for *E-F*.
		40	0.420	1.755	0.425					
IV	*B-C*	70	0.485	1.744	0.472	*C-D*	70	0.497	1.730	
		55	0.507	1.753	0.503		55	0.525	1.741	
		40	0.545	1.744	0.550					
V	*D-E*	70	0.584	1.747	0.580	*B-D*	70	0.584	1.747	
		55	0.600	1.763	0.613	*C-D*	40	0.660	1.755	
		40	0.660	1.755	0.660					
VI	*C-E*	70	0.770	1.737	0.788	*D-E*	70	0.729	1.755	
		40	0.880	1.738	0.864	*C-D*	70	0.850	1.722	
	A-B	55	0.850	1.738	0.822	*B-C*	70	0.815	1.758	
		40	0.895	1.743	.....					
VII	*A-C*	55	1.165	1.753	1.172					
		40	1.340	1.716	1.100	*B-C*				
	C-D	55	1.170	1.748	.....	*A-C*	70	1.11	1.744	All at 70° were made before pipe was set up the second time.
		40	1.340	1.709	.....	*C-D*				
VIII	*A-B*	70	1.53	1.732	1.615	*C-D*	70	1.51	1.737	$V^{1.75}$ diagram for *C-D VII* gives $m = 1.47$ and 1.55.
		55	1.630	1.756	1.675		55	1.64	1.730	
		40	1.74	1.757	1.775					
IX	*A-B*	70	2.04	1.763	2.10	*B-C*	70	2.05	1.760	
		55	2.20	1.751	2.32		55	2.22	1.749	
		40	2.42	1.740	2.36		40	2.40	1.750	
X	*A-B*	70	2.60	1.746	2.58	*B-C*	70	2.60	1.746	
		55	2.72	1.753	2.73		55	2.75	1.745	
		40	2.94	1.741	2.90		40	2.94	1.741	
XI	*A-B*	70	3.03	1.746	3.02	*B-C*	70	3.12	1.744	
		55	3.22	1.747	3.21		55	3.26	1.749	
		40	3.45	1.743	3.41		40	3.51	1.747	
XII	*A-B*	70	3.39	1.744	3.34	*C-D*	70	3.27	1.739	
		55	3.61	1.739	3.52		55	3.48	1.738	

TABLE No. 7.

GALVANIZED PIPES *XVII* TO *XXI*, INCLUSIVE. VALUES OF m AND n (m FOR HEADS IN FEET PER 100).

Pipe.	Temp. Fahr.	m.	n.
XVII		0.820	1.931
XVIII	40°	0.905	1.802
XIX	40	1.320	1.863
XX	70	1.74	1.906
	40	1.81	1.910
XXI		3.52	1.961

CRITICAL VELOCITY.

One of the most interesting features of Plate *XL*, Fig. 1, is the evidence regarding critical velocity. As might be expected, this phenomenon is most prominent on Pipe *XVI*, where the peculiar effects are evident at relatively high velocities. For low velocities, up to 2.5 ft. per second, the slope is 1, showing that the loss of head is directly proportional to the velocity. Above a velocity of 3.5 ft. the slope is about 1.78. Between these velocities there is a region where the slope gradually changes and reaches a value considerably greater than 2. The cause, as Osborne Reynolds, F. R. S., has shown* is a change in the conditions of flow.

The effect of temperature on the point at which the change takes place is well shown by Pipe *XVI*, and also in Fig. 4, which has been prepared from the observations of Hagen.† For these experiments $0.5\frac{V^2}{2g}$ was allowed for head lost at entrance (square-edged). This may not be quite correct. The pipes were short, being 1.55, 3.57 and 3.42 ft. long, for the small, medium and larger sized pipes, respectively. Any other allowance for entry would not change the relative position of the lines to any great extent. The figure has been introduced to show the effect of temperature in the critical-velocity region, particularly for greater temperatures than the writers could obtain, and also to verify the indications of the present experiments. The principal point to be brought out is that the change takes place at higher velocities for lower temperatures.‡ The change to the power

* *Proceedings*, Royal Society, Vol. 35, 1883.

† "Abhandlungen der Berliner Akademie," 1854.

‡ Some recent experiments substantiating this very point came to the writer's notice after this paper had been written. They are by Messrs. E. J. Coker and S. B. Clement, and a record of them appeared in the *Transactions* of the Royal Society, Series A, Vol. 201, pp. 45-61. A single brass pipe, 0.3779 in. in diameter and 6 ft. long, was used. The experiments, also, check closely the temperature factor obtained by the writer's for ordinary, or "eddy motion," flow. The range of temperatures was from 4 to 50° Cent., or 39 to 122° Fahr. The interesting point is made that the intersections of the lines for ordinary and for "stream line" flow vary as the viscosity of the water.

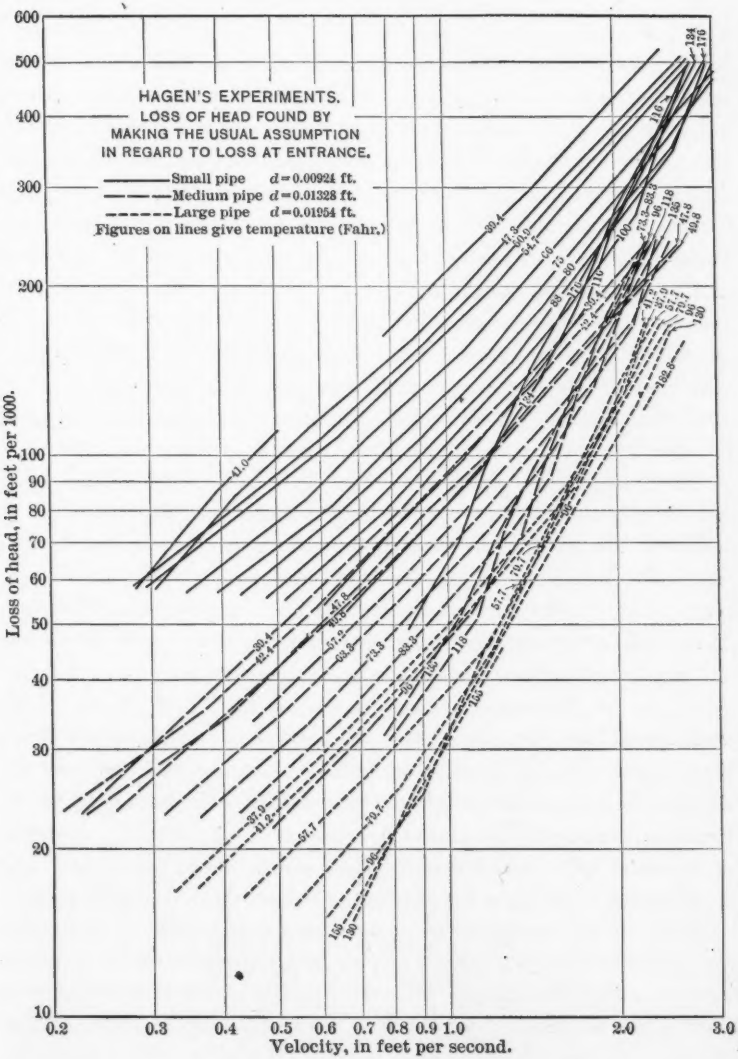

HAGEN'S EXPERIMENTS.
LOSS OF HEAD FOUND BY
MAKING THE USUAL ASSUMPTION
IN REGARD TO LOSS AT ENTRANCE.
Small pipe d = 0.00924 ft.
Medium pipe d = 0.01328 ft.
Large pipe d = 0.01954 ft.
Figures on lines give temperature (Fahr.)
Loss of head, in feet per 1000.
Velocity, in feet per second.
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2.0
3.0

FIG. 4.

1.75, takes place on Pipe *XVI* at a velocity of 3.5 ft. at 70° and at about 5 ft. for 40°. Particular attention is also called to the crossing of the lines, and to the fact that where the loss is proportional to the first power of the velocity the difference in head for any certain temperature interval is many times greater than where the loss is proportional to the 1.75 power of the velocity. For Pipe *XVI* a line is also obtained for 75 degrees. In some pipes, Pipe *IX* for example, where two sections show very slight differences under regular conditions of flow, the differences are magnified below the critical velocity.

The interesting question, however, in connection with the critical velocity, is whether it is an element to be considered for the velocities and pipe diameters used in practice. On the basis of the experiments on brass pipe, and assuming that there is a continuity of law where extended to diameters greater than those experimented upon, the question may be given an approximate answer. The question involves the determination of the relation between the pipe diameter and the velocity at which the power of the velocity ceases to be 1.75.

On Plate *XL* the points for Pipes *XVI*, *XV*, *XIII*, *IX* and *VII*, may be determined fairly well for the experiments at approximately 70 degrees. In addition to these points, the writers have also the evidence of experiments at very low velocities on Pipe *II*. These were made early in 1901, in connection with another study in hydraulics. The heads were measured first with water and later with oil gauges. The region of critical velocity was explored thoroughly. No evidence of the phenomenon was found in the first 68 ft. of pipe down stream from the 5-in. pipe. For this section the ordinary flow equation seemed to hold, down to velocities as low as 0.25 ft. per second. But, in the succeeding length, corresponding to Section *A–B* in the present experiments, the gauges showed a decidedly unstable condition of flow from 0.55 ft. per second down to about 0.35 ft. per second. The temperature of the water for these experiments was about 40 degrees.

The critical-velocity points seem to lie approximately on a straight line. Such a line was drawn, and the intersections with the 70° lines of slope, 1.75, were marked. The velocities thus determined were then plotted logarithmically, with respect to the diameters, and from this plotting the law for impending critical velocity at 70° degrees appears to be $V = \frac{0.088}{d^{0.784}}$. This expression, being only roughly approxi-

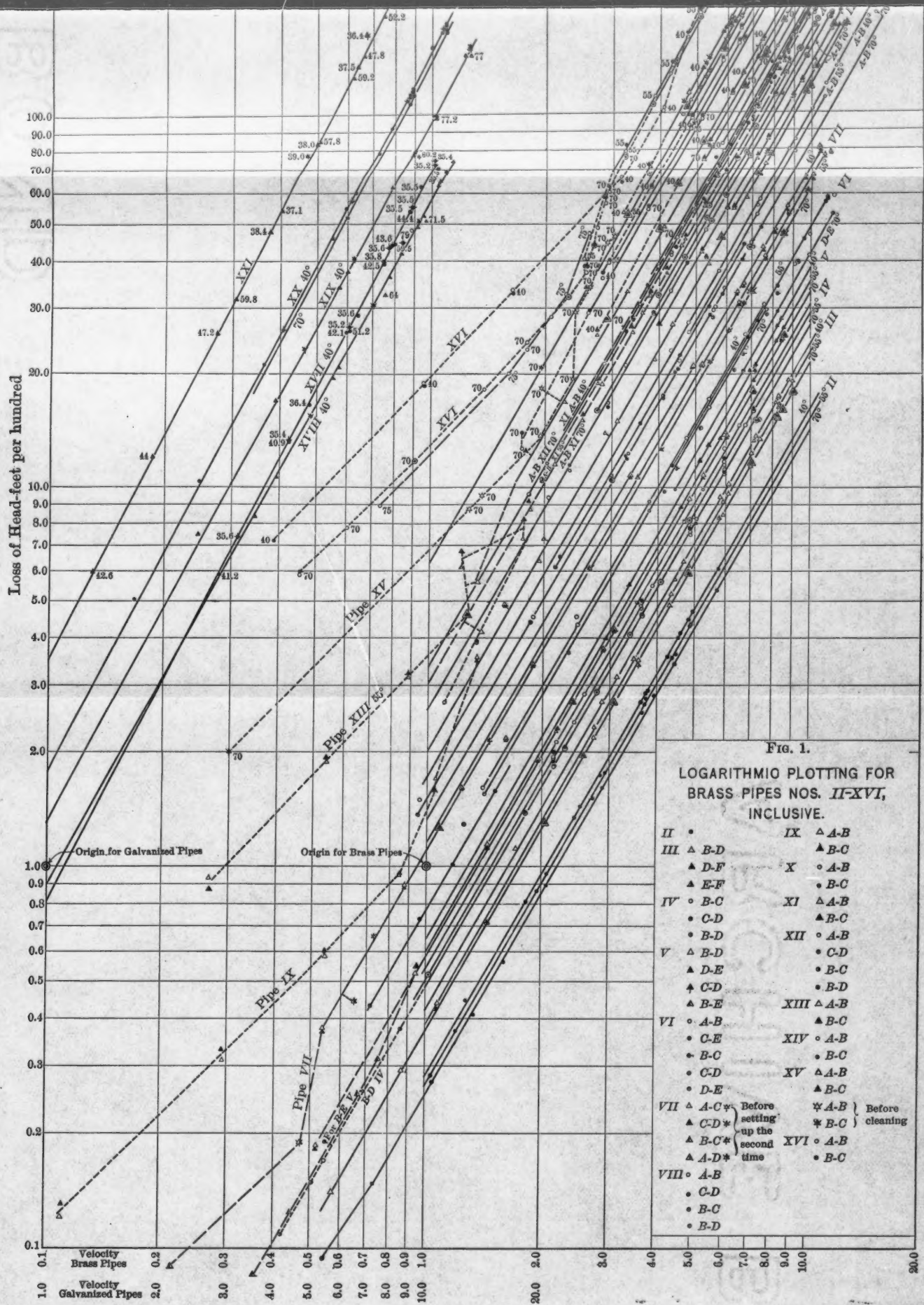


FIG. 1.

LOGARITHMIC PLOTTING FOR BRASS PIPES NOS. *II-XVI*, INCLUSIVE.

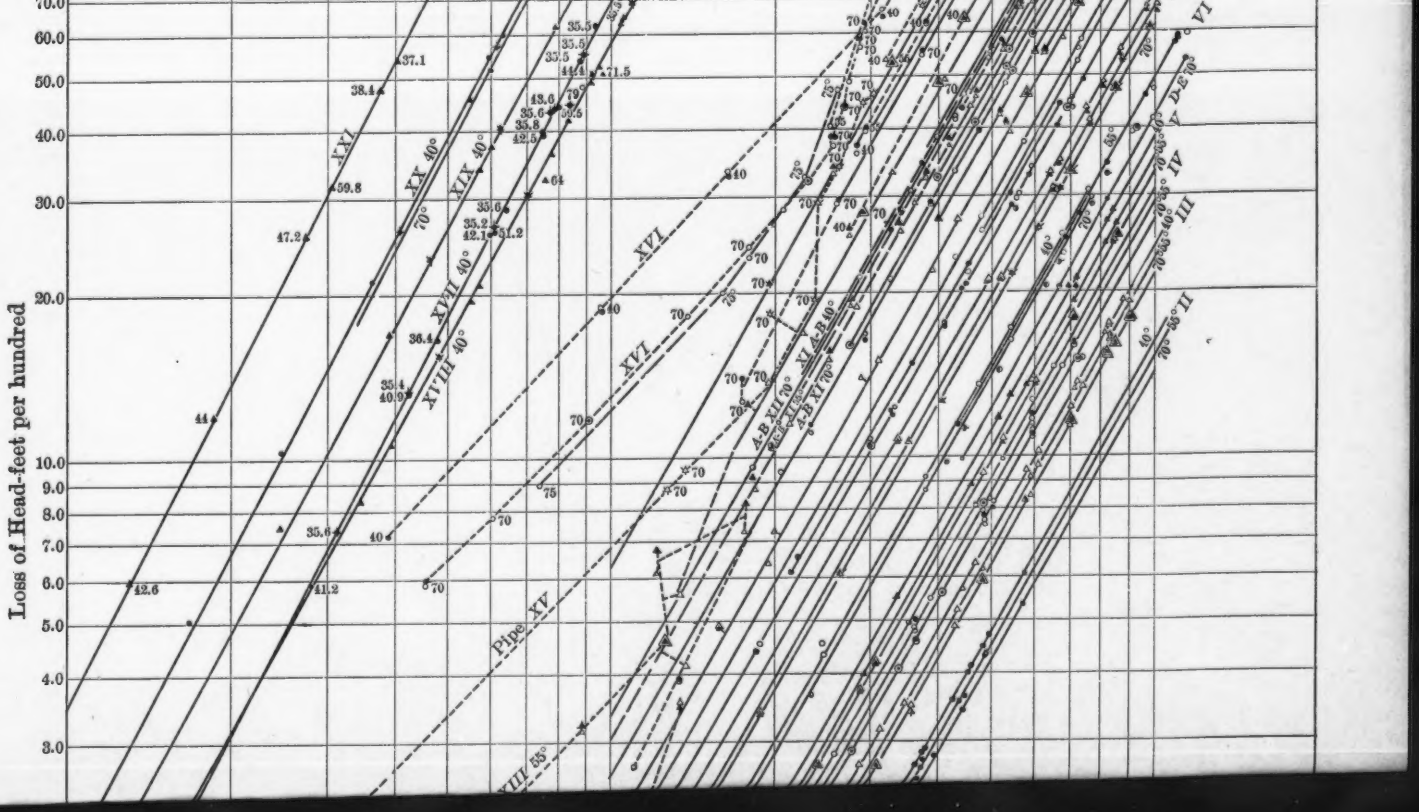
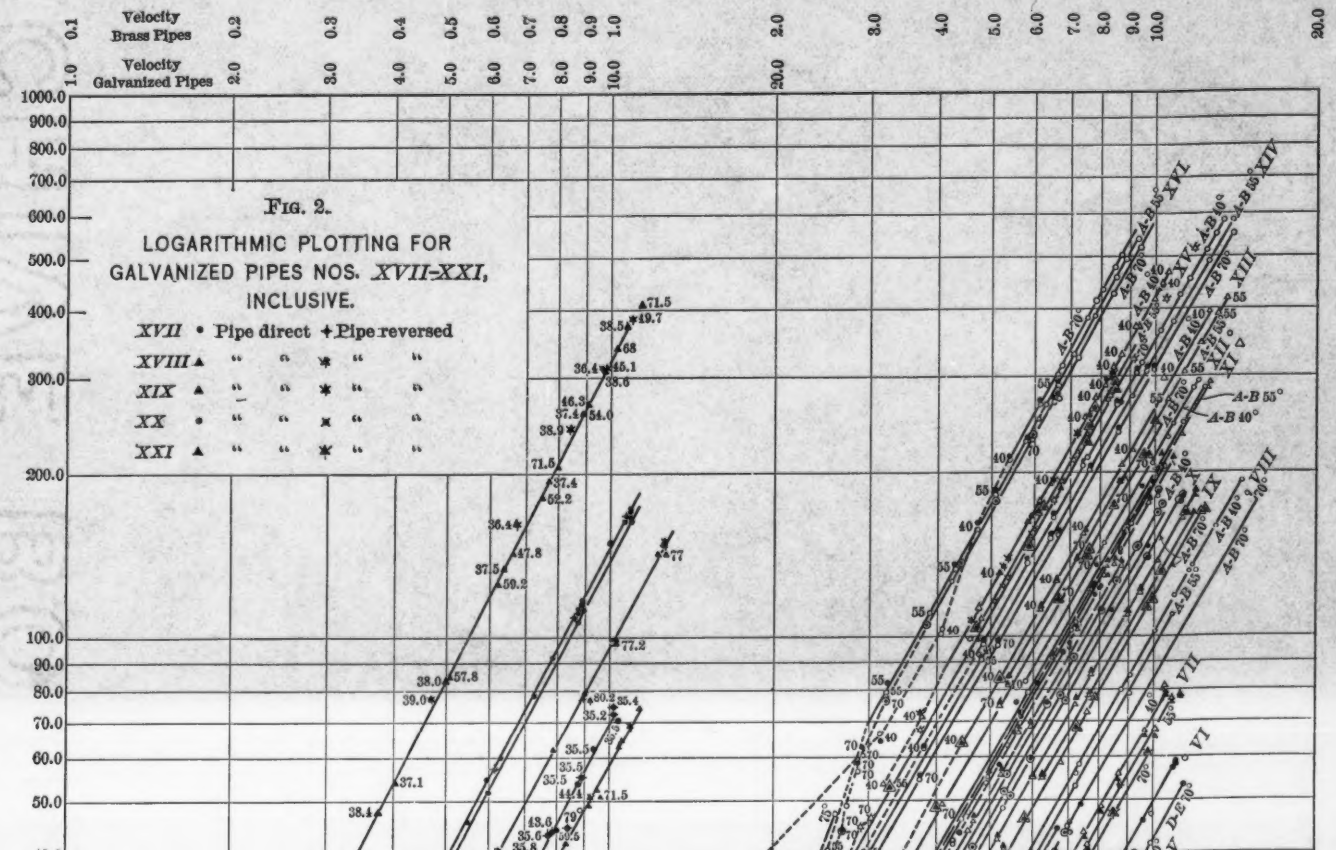

Loss of Head-feet per hundred
70.0
60.0
50.0
40.0
30.0
20.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
XXI
XX 40°
XIX 40°
XVIII 40°
XVII 40°
XVI
XV
Pipe XV
XIII 65°
A-B XII 70°
A-B XI 70°
A-B 40°
VI
V
IV
III
II
70°
75°
65°
40°
37.1
38.4
59.8
47.2
44
42.6
35.6
40
70
75
64
71.5
43.6
35.5
44.4
42.5
35.6
35.2
42.1
31.2
36.4
35.4
40.9
41.2

PLATE XL.
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mate, may be replaced by $V = \frac{0.1}{d^{0.75}}$ (d, in feet). For 40° there are only two points, namely, Pipes *XVI* and *II*, but these indicate the law expressed by $V = \frac{0.15}{d^{0.75}}$.

The older series of experiments do not include many with velocities below 1 ft. per second, and the critical velocity, therefore, is not easily determined. They seem to indicate, however, that the velocities at which ordinary conditions are established are somewhat lower than those given by the foregoing formula. However, it is seen from the formula that the change in condition takes place at very low velocities for ordinary sizes of pipe. Moreover, as appears from Pipe *II*, it seems that, for large sizes, a long length of straight pipe is necessary to allow the below-critical-velocity flow to adjust itself.

The formula given determines only the limiting point for the use of the power, 1.75. The lower points, where the loss ceases to be directly proportional to the velocity, are approximately on the same line that was drawn in the other case, but the intersections must now be taken with the lines of slope 1. The law seems to be about $V = \frac{0.045}{d^{0.85}}$. This law, however, is not of as much interest as the one applying to the upper points.

It seems that the question of critical velocity, while of considerable scientific interest, is of no practical importance to the engineer; but space has been given to its consideration on account of the fact that many scientists have been led astray in attempting to apply experimental data from very small pipes to pipes used by the engineer, simply because the change in the manner of flow was not understood.

Experiments on Small Rubber Hose.

It had been planned to perform a considerable variety of experiments on small hose, especially as regards the effect of curvature on the loss of head. Unfortunately, there was not enough time to follow out by a more extended experimental study the interesting and surprising results obtained.

The hose were fed from the bottom of the large drum, 1.135 ft. internal diameter and 2.167 ft. long, at the up-stream end of the 5-in. brass pipe. A bushing, a 1-in. short vertical nipple, a 1-in. reducer-elbow, a $\frac{3}{4}$-in. short nipple, a $\frac{3}{4}$-in. disc valve, and bushings into which the connecting nipples of the hose screwed, were the fittings, in their

respective order. The valve was wide open during the experiments, the pressure being regulated by a 2-in. valve on the pipe leading into the drum. An air-chamber was attached to the top of the drum, and from this a connecting hose led to a two-column mercury gauge, one arm of which was open to the air. In all the experiments the hose were allowed to drop to the floor (about 6 ft. below the bottom of the drum) and laid straight (curve experiments excepted, of course) along it, except for an easy return curve of about 3 ft. diameter and a slow rise to the sharp downward curve at the discharge end. Thus the entry and discharge conditions were alike in all experiments. The level of the discharge end, with respect to the gauge scale, was determined. An extreme variation of 0.1 ft. might have occurred.

In Experiments Nos. 655 to 658 the hose was laid on a board and held in position in a horizontal plane by means of nails. The loops occurred at the ends of the board where the hose returned on itself. Except at the ends, the curves were semicircles alternating in direction of curvature, the radius being the same as when the hose was wound on the cylindrical drum.

The hose used were of three-ply, cotton-insertion, rubber tubing with smooth interior surfaces. The inside rubber lining was very heavy.

It has been the established idea that reversal of curvature introduces about twice as much loss of head as the same amount of continuous curvature, the length of pipe being the same in the two cases. The experiments on Hose *A* contradict this so flatly that it can only be concluded that there is something radically wrong with the hypothesis underlying the accepted notion. The small size of the hose might be regarded as a bar to the serious consideration of the results, but the experiments of John R. Freeman, M. Am. Soc. C. E., on 2.49-in. hose* are somewhat confirmatory. Mr. Freeman found that a full circle of 2 ft. radius (9.65 diameters) gave practically the same excess loss over straight hose as that given by four quadrants of the same radius, but introducing two reversals of curvature. In figures, the full circle gave $5\frac{1}{2}\%$ less excess loss.

In the curvature experiments on Hose *A*, the data of which are given in Table No. 8, the radius of curvature was $2\frac{15}{16}$ ins., or nearly eight diameters. The amount of curvature was purposely made large so that the effects might show up in no uncertain manner.

* *Transactions*, Am. Soc. C. E., Vol. XXI.

TABLE No. 8.—Experiments on Hose.

Hose A. $l = 47.93$ ft. $d = 0.370$ ins.

No. of experiment.	Temp.	Total acting H, feet of water.	Loss of head, in feet per 100.		Velocity.	Remarks.
647	47.5°	49.01	98.7		8.431	$0.5\frac{V^2}{2g}$ allowed for entry; 647 to 650 hose laid with two easy curves in addition to one at beginning and one at end; 659 same; 651 to 654 hose wound in a spiral of 22 complete turns around a drum of 5¼ ins. diameter; 655 to 658, 39 curves, including 3 loops; 38 reversals of curvature: curves of same radius as in 651 to 654. In curve experiments there were curves also at beginning and end as in 647 to 650.
648	.....	38.14	77.0	If laid as in 647 to 650.	7.343	
649	.....	27.03	54.6		6.066	
650	49	14.18	28.7		4.228	
651	.....	49.10	99.9	75.5	7.248	
652	49	38.14	77.6	60.0	6.371	
653	49.5	23.37	47.5	37.3	4.886	
654	51	11.23	22.9	17.9	3.241	
655	51	49.10	99.4	84.6	7.733	
656	51.2	38.14	77.3	66.6	6.760	
657	.....	25.16	51.0	45.0	5.423	
658	53.0	12.34	24.9	22.6	3.692	
659	51	49.05	98.9	.....	8.418	

Hose A_1. $d = 0.380$ in.

684	49	49.09	94.8	.....	7.640	$0.5\frac{V^2}{2g}$ allowed for entry.
685	49.5	34.59	66.7	.....	6.307	
686	50.5	16.73	32.4	.....	4.273	$l = 50.28$ ft.
678	60	49.22	47.9	.....	5.488	Used $A + A_1$ ($l = 98.58$ ft.) and subtracted A, using a diagram based on Experiments 647 to 650.
679	61	36.63	35.4	.....	4.674	
680	62.2	22.08	21.6	.....	3.504	
681	63.5	8.86	8.7	.....	2.103	
682	50	49.03	49.1	.....	5.393	
683	42.4	74.05	73.8	.....	6.787	

For A_1.

Hose B_1. $l = 11.87$ ft. $d = 0.504$ in.

687	45	48.10	340.5	.....	18.076	$0.5\frac{V^2}{2g}$ allowed for entry.
688	44.5	36.98	262.5	.....	15.781	
689	44	24.79	176.3	.....	12.854	
690	44	14.71	104.9	.....	9.829	
691	44	7.85	56.3	.....	7.078	
692	36.5	72.26	511.1	.....	22.240	

Hose B. $d = 0.519$ in.

693	43.5	48.80	77.1	.....	7.731	Used $B_1 + B$ ($l = 61.82$ ft.) and subtracted B_1, using a diagram based on Experiments 687 to 692.
694	43	33.68	53.2	.....	6.370	
695	43.5	18.77	29.9	.....	4.649	
696	44	9.71	15.7	.....	3.243	
697	39	74.39	116.7	.....	9.728	

For B.

Hose C. $l = 14.37$ ft. $d = 0.254$ in.

698	69	49.56	325.9	.....	10.750	$0.5\frac{V^2}{2g}$ allowed for entry.
699	60.5	36.63	240.8	.....	9.255	
700	58.5	24.73	162.8	.....	7.520	
701	58	14.48	95.6	.....	5.627	
702	58	8.17	54.1	.....	4.082	
703	60	4.53	30.1	.....	2.973	
704	63	49.31	324.4	.....	10.757	
705	50.5	49.14	322.7	.....	10.815	
706	47	48.99	321.9	.....	10.750	
707	44	75.00	490.7	.....	13.764	
708	43	49.81	327.2	.....	11.088	

The most surprising result was, that, although each series showed a most decided effect on the loss of head and the discharge, the value of n, in the formula $H = m\ V^n$, remained practically constant, the large changes being in the value of m. (There is a small increase for the case of reversed curvature.) Should this result be confirmed by further experiments along this line, it will have an important bearing on the subject of the nature of the resistances which cause loss of head in a pipe. For it would appear that the value of the exponent, n, is determined solely by the nature of the inner surface of the pipe, while m depends on the distribution of the velocities throughout the cross-section, and on the temperature.

The fact that the reversed curves caused only about half as much increase of resistance as the continuous curves is certainly something to think about. It is to be hoped that further and more elaborate experimentation may bring out the laws which govern the resistances in various cases of flow in curves. It may not be out of place to suggest the bearing of such studies, not only on sinuous supply mains, but also on the flow in turbine wheels.

The results of the experiments on the hose when laid with easy curves and tangents are of interest in their relation to the results of the brass and galvanized pipes. The values of m and n, as obtained from a logarithmic plotting, are as follows:

Hose.	Diameter.	m, in feet per 100 ft.	n.
A	0.370 in	2.24	1.78
B	0.519 "	1.82	1.82
B_1	0.504 "	1.32	1.91
C	0.254 "	4.2	1.81

The experiments on B_1 were made with high velocities (7 to 22 ft. per second), and it is probable that the usual allowance for entry loss is insufficient, the velocities in the $\frac{3}{4}$-in. fittings being considerable. The high value of n and the low value of m bear out this statement. Hose B is free from this objection.

Especial attention is called to the low values of n for Hose A, B and C.

Experiments on Entry Loss.

The writers made some experiments to investigate the commonly accepted value for loss of head due to a square-edged entry. The

experiments were made on Pipes *II* and *X*. For Pipe *II* the cycloidal mouthpiece at the junction of the 5-in. brass pipe was replaced by a specially turned brass bushing with a plain inside face. The opening in this is 2.096 ins. in diameter, the same as Piezometers *A* and *B*. Section *A*-*B* of Pipe *II* was moved up stream next to the 5-in. pipe, and Piezometer *A* was inserted between the first two pipe lengths of the section. The slight ridge where the pipe was screwed up against a shoulder in the bushing was smoothed down. The entry length of Pipe *X*, likewise, was screwed into a brass bushing, giving a square-edged entry. An air-chamber was substituted for the end air-cock on top of the header, and the pressure was taken from this. The diameter of the header (2½ ins.) is so large, relatively to Pipe *X*, that practically static conditions prevailed. For Pipe *II*, however, the effect of the small velocity in the 5-in. pipe on the up-stream piezometer has been considered.

The results are given in Table No. 9. It will be seen that the values for Pipe *II* check fairly the accepted value, $0.5\frac{V^2}{2g}$. Pipe *X*, however, gives lower indications, the values seeming to average about $\frac{1}{3}\frac{V^2}{2g}$. These results indicate the possibility of a higher value than $0.5\frac{V^2}{2g}$ for pipes of commercial size.

Extent of Entry Disturbances in Succeeding Tangent.

The experiments on Pipe *II* seem to show that the piezometric effects of a square-edged contraction do not extend 78 diameters down stream. Section *A*-*B* gives normal results. In Pipe *X*, on the other hand, Experiments 666 to 670 show that 43 diameters are not sufficient, for both the high results for entry loss and the low results for the loss in Section *A*-*B* show that Piezometer *A* was in the abnormal-flow region. With these results the evidence obtained by the writers on the effects of curves* should be compared.

Practical Deductions.

The engineer will ask: "Of what use are refined laboratory experiments on pipes with conditions never met in practice?" Waiving the answer, for the present, let us examine the evidence to be had on the general subject of the flow of water in pipes.

* *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 317.

TABLE No. 9.—Entry Loss.

A.—Pipe II.

No. of experiment.	Temperature.	Observed head in water in section between Piezometer in 5-in. pipe to piezometer A in 2-in. pipe. Double centimeters.	Observed head in Section A-B in water. Double centimeters.	Loss of head due to entry, A-B considered normal. Double centimeters.	Velocity in Pipe II, in feet per second.	Remarks.
733	36.2°	22.89	39.92	$3.50 = 0.475 \frac{V^2}{2g}$	5.611	The up-stream section consists of 3.5 ft. of 5-in. pipe and 13,543 ft. of 2-in. pipe. Length A-B = 44.635 ft. Square-edged contraction. A-B is normal, since loss is the same as in other experiments.
734	36.0	16.85	29.95	2.48 = 0.454 "	4.811	
735	37.0	5.46	10.34	0.79 = 0.503 "	2.594	
736	36.8	10.61	19.40	1.50 = 0.453 "	3.761	

B.—Pipe X.

No. of experiment.	Temperature.	Observed head in Section Header-A. Double centimeters of mercury.	Observed loss of head in Section A-B. Double centimeters of mercury.	Loss due to entry alone, A-B considered normal in each case. Double centimeters of mercury.	$\frac{V^2}{2g}$ in double centimeters of mercury.	Velocity, in feet per second.	Loss in A-B, in feet per 100. Water.	Remarks.
660	54.5°	14.16	13.93	$0.71 = 0.393 \frac{V^2}{2g}$	2.13	10.628	170.7	In 660 to 665:
661	56.1	21.20	20.56	1.16 = 0.348 "	3.34	13.319	252.0	l (entry) = 5.459 ft.
662	57.8	8.50	8.48	0.40 = 0.330 "	1.21	8.011	103.9	l (A-B) = 6.719 "
663	47.8	8.60	8.64	0.40 = 0.339 "	1.18	7.924	105.9	
664	48.8	14.18	14.04	0.69 = 0.332 "	2.08	10.506	172.0	
665	50.9	5.38	5.47	0.23 = 0.324 "	0.71	6.136	67.0	In 666 to 670:
666	63.9	5.27	13.62	0.81 = 0.378 "	2.14	10.672	167.1	l (entry) = 1.144 ft.
667	46.2	5.17	13.94	0.76 = 0.372 "	2.04	10.407	170.8	l (A-B) = 6.719 "
668	48.0	3.63	9.93	0.54 = 0.386 "	1.40	8.611	121.7	
669	50.4	2.11	6.01	0.31 = 0.398 "	0.78	6.456	73.6	
670	52.0	7.94	20.38	1.22 = 0.376 "	3.25	13.150	249.7	
671	79.5	15.06	10.05	0.67 = 0.330 "	2.03	10.396	151.9	In 671 to 676:
672	82.9	22.63	14.89	1.09 = 0.339 "	3.22	13.076	225.2	l (entry) = 6.720 ft.
673	52.8	15.44	10.45	0.68 = 0.358 "	1.90	10.047	157.6	l (A-B) = 5.462 "
674	51.2	4.55	3.18	0.16 = 0.334 "	0.48	5.070	47.9	
675	51.8	9.26	6.34	0.38 = 0.352 "	1.08	7.588	95.6	
676	53.0	24.54	16.36	1.21 = 0.378 "	3.20	13.044	246.6	

Wherever possible, the original records of experimental data have been consulted. By the method of logarithmic plotting of losses of head with velocities, some 150 series of experiments have been investigated, and the values of m and n determined. The writers early came upon the necessity of either considering all the evidence, or else of running the risk of making errors in judgment and perhaps of allowing partiality more play than desirable in such a study.

In the preliminary plotting, all experiments which had been investigated were considered. In the final plotting many are left out. But the writers can state conscientiously that the conclusions are not altered thereby. The experiments omitted from the plotting are mostly old German and English experiments, the exact conditions and methods of measurement being generally unknown. If they were included (and the writers were sorely tempted to do so on account of the indications of most of them) they could not be given much weight, no matter what the indications, on account of this uncertainty.

Considering now the general subject, there is presented on Plate XLI a logarithmic plotting of the values of m (as determined from plottings of each series of experiments), with the diameters of the pipes. It will be noticed that the values of n are marked near the points. These serve as descriptions of the nature of the pipe, from the experimental standpoint. In addition to this, the material is also indicated. This latter is the engineer's description, and is usually far from complete, but, with the assistance of the knowledge of the value of n, the indications can be discussed more rationally.

It will be seen that the range of pipe diameters varies from $\frac{1}{16}$ in. to 12 ft. A very casual examination will show that all the points lie in a comparatively narrow zone and hence indicate some exponential relation.

First of all, the line best fitting the points for the writers' brass pipes has been drawn. On account of the very considerable effect of temperature on the value of m, the middle points, for 55°, have been used. There are plotted, also, the points for 40° and 70°, but these are not used, except to convey to the eye the magnitude of temperature effect.

The variations in the value of n for the seamless-drawn brass pipes (all apparently of the same degree of roughness), have been noted. Hence, corresponding indications due to the values of m are to be

TABLE No. 9.—ENTRY LOSS.

A.—PIPE II.

expected, and the variations from the line which has been drawn are seen on Plate XLI.

One feature will be noticed at once. The line for the brass pipes forms the lower limit of the zone in which all the plotted points lie. This is another way of stating that these pipes represent the extreme of smoothness and ideal conditions. The equation of this line, neglecting the third place of decimals in the exponent, is

$$m = \frac{0.296}{d^{1.25}}$$

in which m is in feet per 1 000 ft., and d is in feet. Placing this value in the general expression, $H = m\ V^n$, and using the average value of n, there results

$$H = \frac{0.296}{d^{1.25}}\ V^{1.75}$$

in which H is in feet per 1 000 ft., and d is in ft. This expression, then, gives the loss of head for extremely smooth pipes laid straight. But this is not all. There occur maximum variations in the value of m of approximately 7% each way from the line of this equation. Hence, it is seen that this variation must be taken into account. There is also an effect due to the variation in n, and this may become considerable for high velocities. It is not as prominent a factor in the smooth brass pipes as in pipes used in practice, but it is pointed out as something to be borne in mind. The writers might wish, as many hydraulic engineers have wished, that there was less uncertainty in designing pipe systems, but, since it exists, its probable extent should be made an integral part of any formula. Therefore, concerning smooth brass pipes, under nearly ideal conditions, it becomes necessary to write, for the general expression,

$$H = \frac{0.296}{d^{1.25}}\ V^{1.75} \pm 7\%.$$

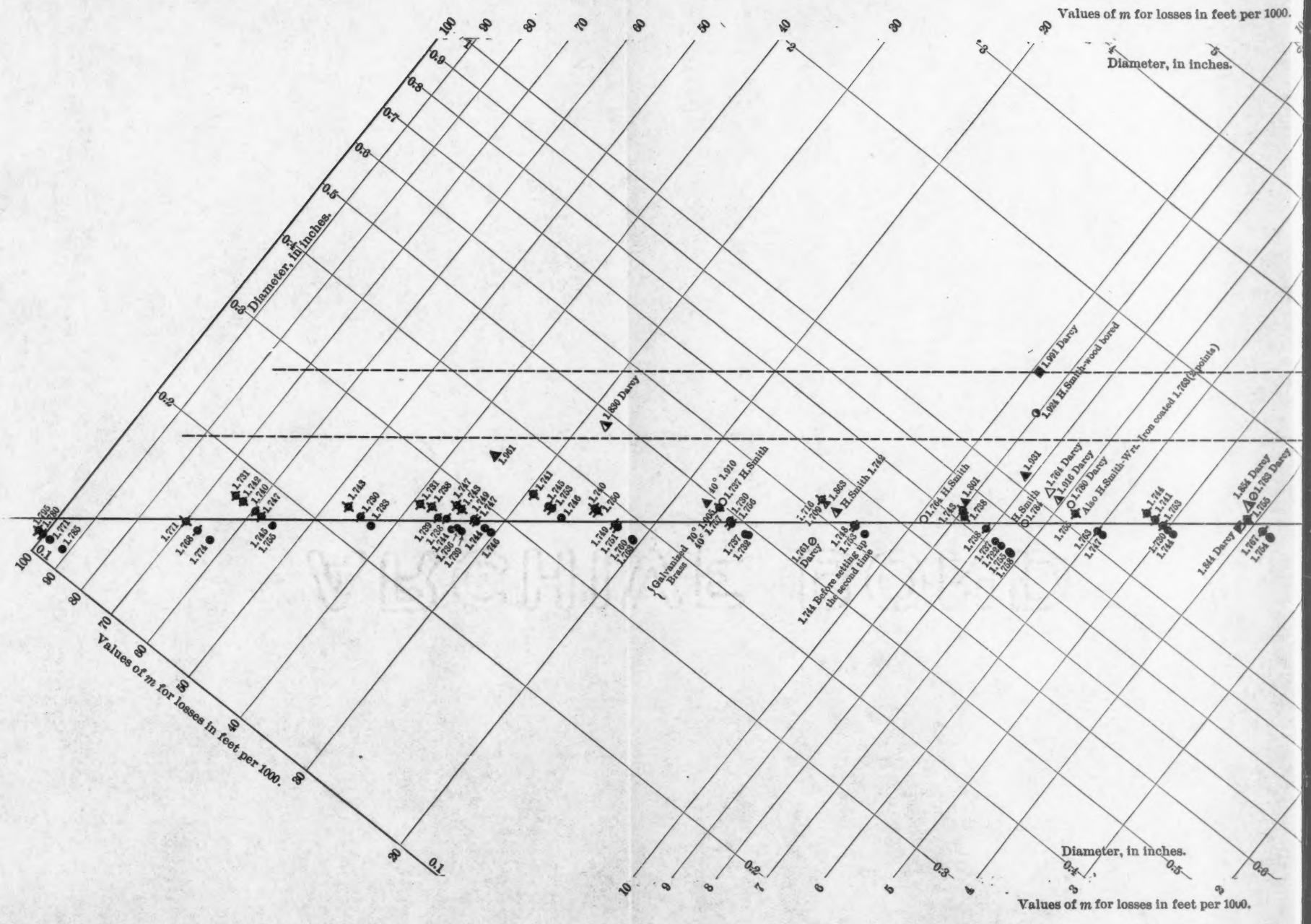
Looking at this, and remembering the long months of monotonous experimentation, the care taken to have everything accurate, the temperature factor, which alone may cause a variation as large as that given above, the writers feel that it nevertheless represents a step in advance; for while it does not tend to make hydraulic science any more exact, it at least helps to make it safer in application.

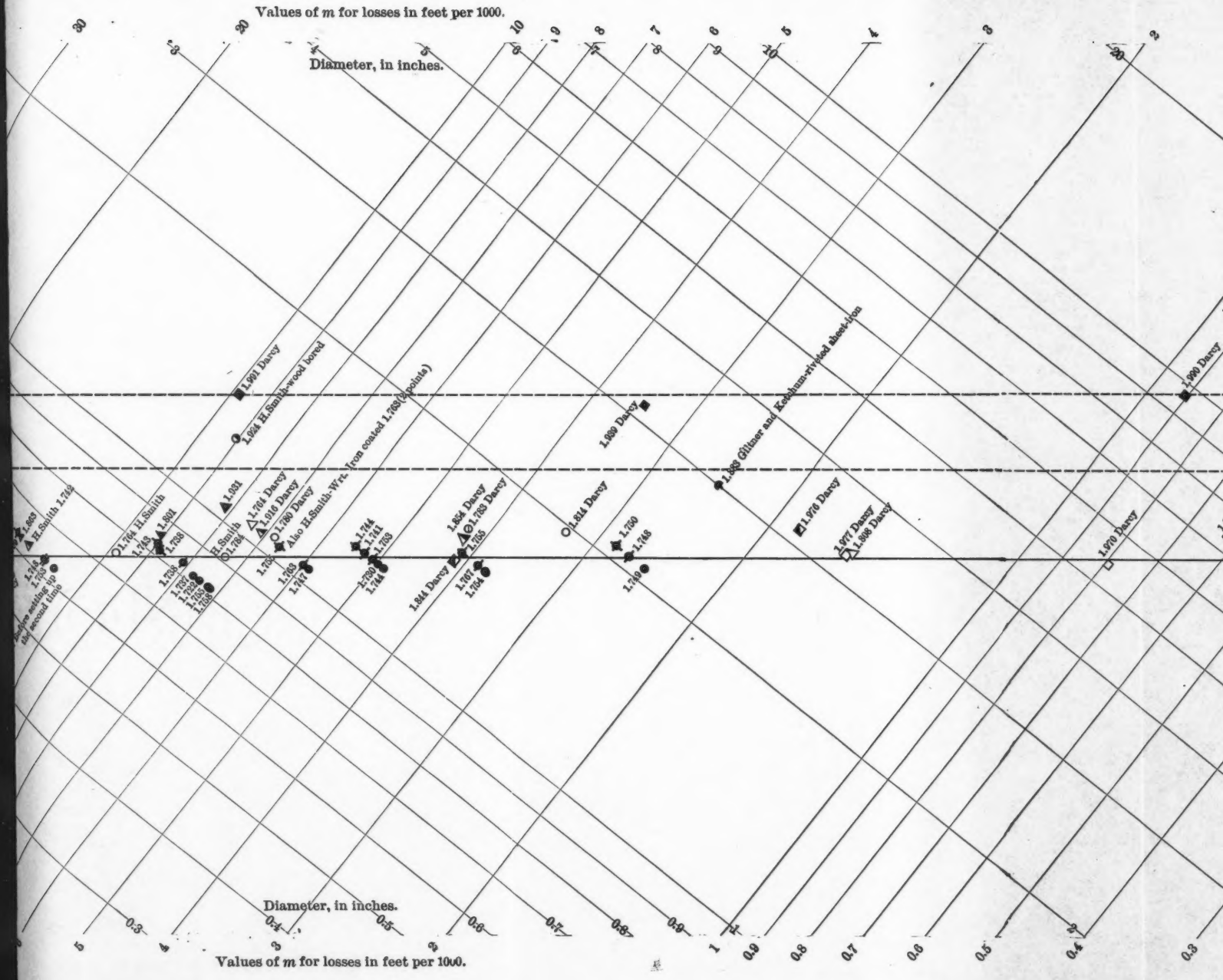
Modifying the above formula, there is obtained the expression

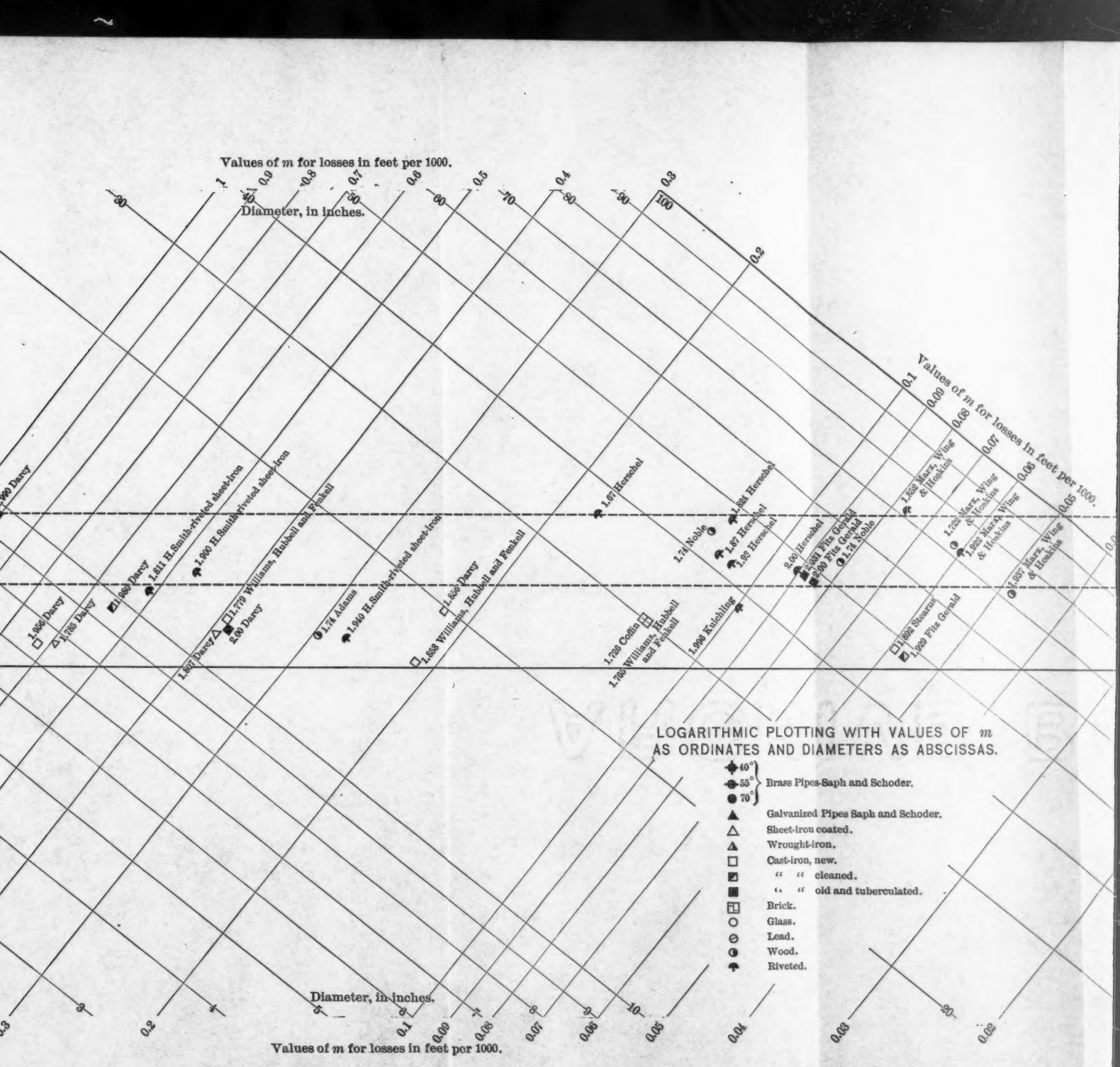
$$V = 104\ s^{0.57}\ d^{0.71} \pm 4\%;$$

or, using the "hydraulic mean radius,"

$$V = 279\ s^{0.57}\ R^{0.71} \pm 4\%.$$


Values of m for losses in feet per 1000.
Diameter, in inches.
Values of m for losses in feet per 1000.
Diameter, in inches.
Values of m for losses in feet per 1000.
1.930 Darcy
1.901
1.991 Darcy
1.924 H.Smith-wood bored
1.701 Darcy
1.916 Darcy
1.730 Darcy
Also H.Smith-Wrt.-Iron coated 1.763(3 points)
1.654 Darcy
1.544 Darcy
1.763 Darcy
1.761 Darcy
1.744 Before setting up the second time
{Galvanized Brass
40° 1.910
40° 1.905
70° 1.901
1.737 H.Smith
1.716
1.763
H.Smith 1.749
1.764 H.Smith
1.801
1.931
H.Smith
1.764


Values of m for losses in feet per 1000.
Diameter, in inches.
1.991 Darcy
1.924 H.Smith-wood bored
1.989 Darcy
1.999 Darcy
1.969 Gilmer and Ketchum-riveted sheet-iron
1.976 Darcy
1.977 Darcy
1.908 Darcy
1.970 Darcy
1.931
1.704 Darcy
1.916 Darcy
1.730 Darcy
Also H.Smith-Wrt.-Iron coated 1.768(3 points)
1.654 Darcy
1.763 Darcy
1.844 Darcy
1.814 Darcy
1.764 H.Smith
1.801
1.738
1.744
1.741
1.733
1.760
1.744
1.767
1.754
1.750
1.748
1.749
Diameter, in inches.
Values of m for losses in feet per 1000.


Values of m for losses in feet per 1000.
Diameter, in inches.
Values of m for losses in feet per 1000.
Diameter, in inches.
Values of m for losses in feet per 1000.
1.956 Darcy
1.788 Darcy
1.880 Darcy
1.811 H.Smith-riveted sheet-iron
1.900 H.Smith-riveted sheet-iron
1.807 Darcy
1.779 Williams, Hubbell and Fenkell
2.00 Darcy
1.74 Adams
1.940 H.Smith-riveted sheet-iron
1.656 Darcy
1.658 Williams, Hubbell and Fenkell
1.738 Coffin
1.760 Williams, Hubbell and Fenkell
1.996 Kuichling
1.67 Herschel
1.74 Noble
1.824 Herschel
1.67 Herschel
1.82 Herschel
2.00 Herschel
2.03 Fitz Gerald
2.00 Fitz Gerald
1.74 Noble
1.852 Marx, Wing & Hoskins
1.722 Marx, Wing & Hoskins
1.922 Marx, Wing & Hoskins
1.937 Marx, Wing & Hoskins
1.852 Stearns
1.999 Fitz Gerald
LOGARITHMIC PLOTTING WITH VALUES OF m AS ORDINATES AND DIAMETERS AS ABSCISSAS.
40°
55°
70°
Brass Pipes-Saph and Schoder.
Galvanized Pipes Saph and Schoder.
Sheet-iron coated.
Wrought-iron.
Cast-iron, new.
" " cleaned.
" " old and tuberculated.
Brick.
Glass.
Lead.
Wood.
Riveted.

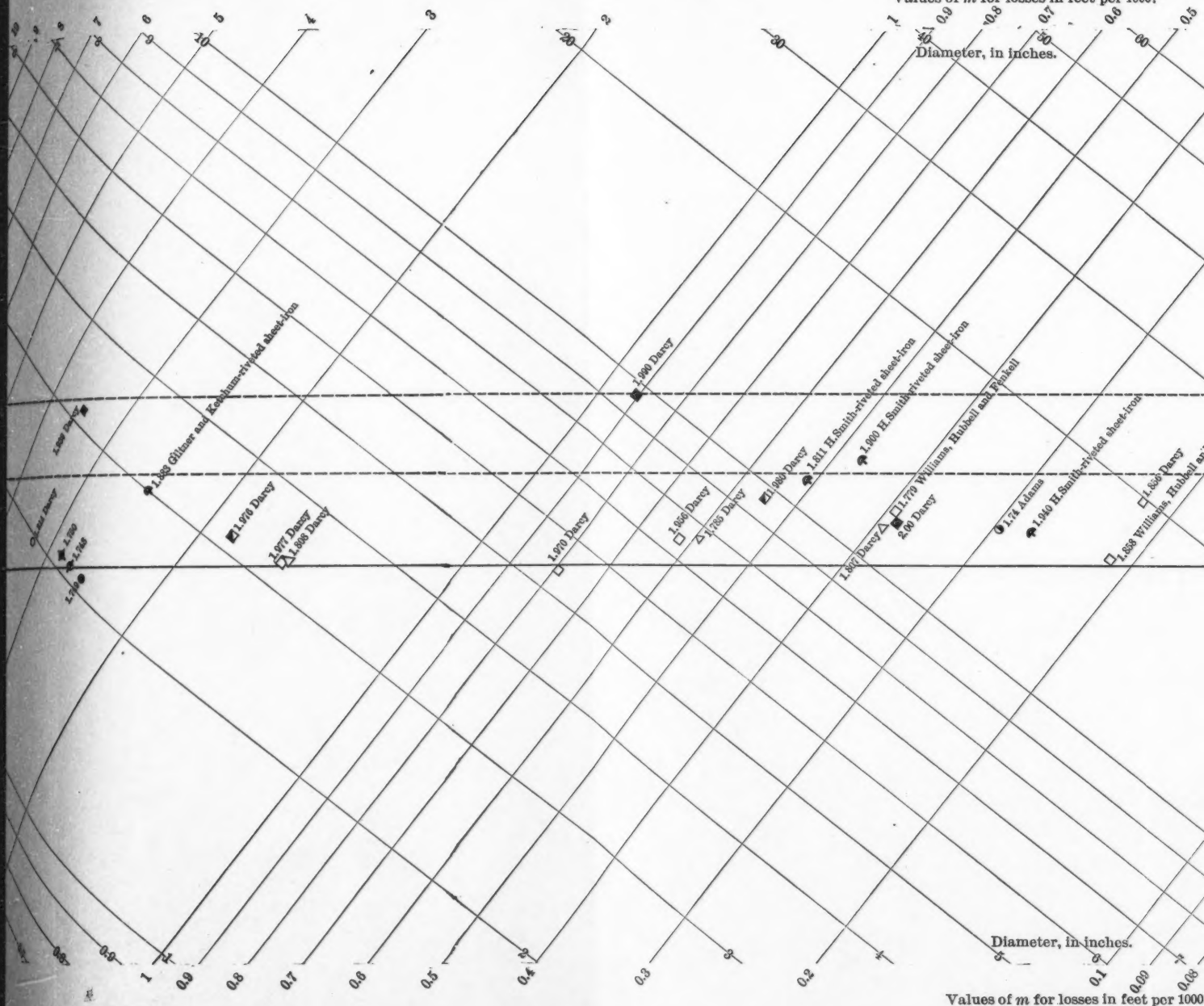
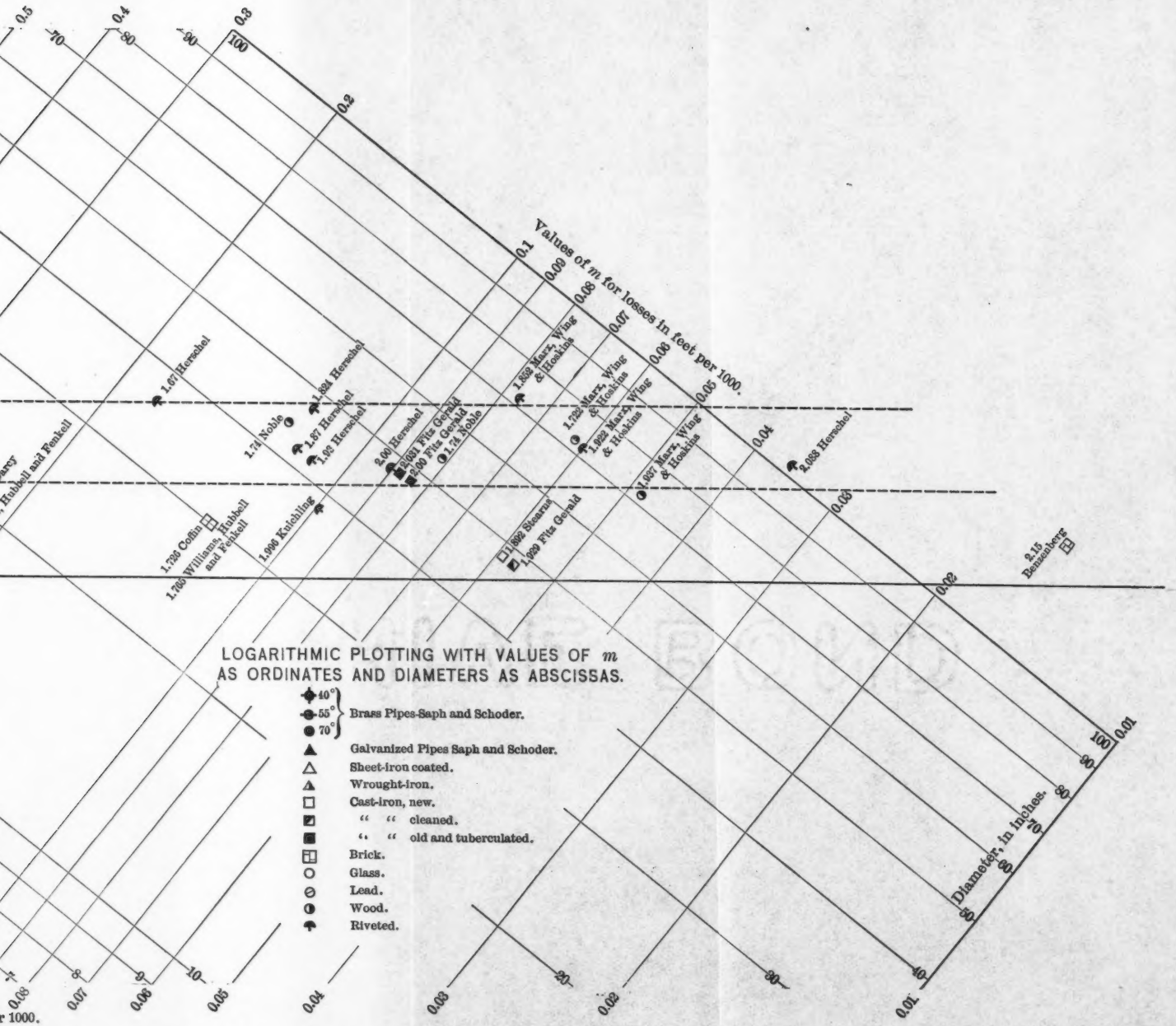

Values of m for losses in feet per 1000.
Diameter, in inches.
1.999 Darcy
1.983 Gilmer and Kelham-riveted sheet-iron
1.976 Darcy
1.977 Darcy
1.905 Darcy
1.970 Darcy
1.956 Darcy
1.795 Darcy
1.990 Darcy
1.811 H.Smith-riveted sheet-iron
1.900 H.Smith-riveted sheet-iron
1.779 Williams, Hubbell and Fenkell
2.00 Darcy
1.807 Darcy
1.74 Adams
1.940 H.Smith-riveted sheet-iron
1.858 Williams, Hubbell and
Diameter, in inches.
Values of m for losses in feet per 1000

PLATE XLI.
PAPERS, AM. SOC. C. E.
MAY, 1903.
SAPH AND SCHODER ON
FLOW OF WATER IN PIPES.



In these last expressions s is the hydraulic slope, in feet per foot of length. In these expressions temperature effect has not been included. As has been stated, the effect is to vary the loss of head about 4% for a change of 10° Fahr. Owing, however, to the uncertainty regarding the effect on the rougher pipes used in practice, the writers feel that its insertion might be misleading.

Commercial Pipes.—Considering now the kinds of pipes used in practice, the writers desire, first of all, to call attention again to the indications of their experiments on galvanized-iron pipes. It is seen that, not only is there a variation in the exponent, n, from 1.80 to 1.96, but that Pipe *XVIII*, although having but two-thirds the internal sectional area of Pipe *XVII*, nevertheless, has a decidedly greater discharging capacity per unit of sectional area, or, in other words, offers less resistance to the flow, for the same velocity. Nevertheless, to the eye, all the pipes appear to be of the same degree of roughness. These two facts throw a strong illumination on the hitherto unaccountable variations in the results of standard experiments.

Although Darcy's experiments showed clearly the effect of variations in roughness which were easily perceptible, and which could be described so as to be recognized by ordinary inspection, yet the hydraulic literature of the past decade or two bears out the statement that the extent of the effects of variations in character of surface which practically defy detection have not been appreciated. Otherwise, how can we account for statements by well-known engineers that certain formulas will give results within 2 or 3% of the truth?

Turning again to the general plotting on Plate XLI, we have to consider the experiments which lie in the zone, one of the limits of which is the line already discussed. Attention should be called to the fact that some of the series of experiments do not show much harmony in the indications, and that, therefore, it is a matter of judgment just where to draw the line on the logarithmic plotting of the losses of head and velocities. Hence, the values of m and n have the effects of the personal equation. But the two values, taken together, represent, as well as may be, the conditions in the range of the series under investigation.

It will be seen that the variations in the value of the exponent, n, are greater than the variations found by the writers for the galvanized pipes. Outside of the heavily tuberculated and riveted pipes, this

variation is from 1.74 to 2.00. The exponents given for the series by Herschel and by Darcy represent fairly the point which has been made. The values of m and n for the 30-in. pipe of Williams, Hubbell and Fenkell have been furnished to the writers by Professor Williams. They are the result of a plotting of the original data, on their own merits.*

It will be seen that a line parallel to the one already drawn will represent fairly the other limit of the zone. The experiments which determine this line are those by Darcy on tuberculated, cast-iron pipe, and some of those by Herschel and some by Marx, Wing and Hoskins on riveted-steel pipe. Noble's 44-in. wood-stave pipe also comes close to this line. The equation is $m = \frac{0.687}{d^{1.25}}$. As for the general equation, we have a variation in the value of n from 1.67 to 1.99. The value, 1.67, from Herschel's 36-in. pipe, is lower than anything else on the plate. The writers consider that this value is questionable, although it is what the series of experiments gave.† Hence, the variation in n will be considered as from 1.82 to 1.99, and the general formula becomes

$$H = \frac{0.687}{d^{1.25}} V^{1.82 \text{ to } 1.99}$$

in which H is in feet per 1 000 ft., and d is in feet. Converting this into the other form, there appears

$$V = 54.7 \text{ to } 38.9\, s^{0.55 \text{ to } 0.50}\, d^{0.69 \text{ to } 0.63}.$$

Using the hydraulic radius, this becomes

$$V = 142 \text{ to } 93\, s^{0.55 \text{ to } 0.50}\, r^{0.69 \text{ to } 0.63}.$$

The two sets of equations thus far given, then, may be regarded as giving the two extremes, the first for very smooth pipes laid very straight, and the second for a considerable degree of tuberculation (or an inner surface comparable to it).

But neither one of these formulas represents the great majority of cases which confront the hydraulic engineer. These latter are included in the zone bounded by the full line and the middle line on Plate XLI. The values of n vary from 1.74 to 2.00. The equation is $m = \frac{0.296 \text{ to } 0.469}{d^{1.25}}$ and the general expression becomes

$$H = \frac{0.296 \text{ to } 0.469}{d^{1.25}} V^{1.74 \text{ to } 2.00}.$$

* Not as described in *Transactions*, Am. Soc. C. E., Vol. XLVII, pp. 113 and 188.
† Mr. Herschel, himself, questions the reliability of seven out of eight experiments.

In the second form, this gives

$$V = 107 \text{ to } 46\, s^{0.57 \text{ to } 0.50}\, d^{0.72 \text{ to } 0.62},$$

or

$$V = 289 \text{ to } 109\, s^{0.57 \text{ to } 0.50}\, r^{0.72 \text{ to } 0.62}.$$

This last series of equations may be said to represent the range of results which the best modern experimenters have obtained on actual pipe lines in service or ready for service. The range of values is large, but the writers do not desire to narrow the analysis any more at present. Their purpose will have been accomplished if this paper serves to bring out some of the factors which have been neglected or not fully appreciated in the past. Above all, it is hoped that a vigorous discussion, in the true scientific spirit, may result, and that less of personality and more of the truth may appear than is wont to be the case.

The experiments, the data of which are given in this paper, were performed between February 24th, 1902, and February 25th, 1903. Experiments Nos. 25 to 771 were performed after July 10th, 1902. Earlier preliminary experiments, during 1901, are noted in the paper.

The original notes and the data tabulated from them are on file in the Hydraulic Laboratory of the College of Civil Engineering of Cornell University, where they are available for examination at any time.

APPENDIX.

Discussion of Theories.

The writers do not venture, at present, to give any hypothesis showing why the exponent for smooth pipes should be 1.75. They merely give it as an experimental fact.

There has been an attempt, however, to explain the matter by saying that the resistance is really composed of two parts, one due to the true friction on the pipe wall, and depending on the first power of the velocity, and the other due to the impacts of the particles on each other and depending on the square of the velocity. The theory states that the composition of these two parts will be equivalent to one term with the power, 1.75. The formula which expresses this idea is $H_f = xV + yV^2$, x and y being coefficients, the values of which are to be determined. Since this formula (or its many modifications) has been used extensively, and since it expresses the idea put forth above, the writers have investigated it, to see, if in this form or in any of its modified forms, it can be made to represent accurately a series of experimental results.

In order to determine the values of the coefficients x and y, at least two methods have been in vogue. The first—the method of least squares—is allowable only on condition that the coefficients are proved to be constants, otherwise the formula derived and its limits of error apply only to those experiments which are used, and its application may be limited. The second method—a graphical one—is for this reason more general, but in most cases in which it has been applied it has not been carried to completion. It consists in obtaining first a series of equations in x and y by substituting the observed values of H_f and V. These equations may be represented by straight lines, and, if x and y are constants, all these lines should pass through one point the coördinates of which are the desired values. Ordinarily, however, it is said that the lines will not pass through a point, but will enclose a small area, and in such a case the coördinates of the center of gravity of the area are the values of x and y. This method has been applied by the writers to a number of series of experiments, and in no case, if a suitable scale was used, did the lines pass through a point or enclose an area. In every case the lines formed a series of tangents to a regular curve similar to one branch of a hyperbola, and to which the axes were apparently asymptotic. This showed clearly that x and y, instead of being constants, were really functions of V. Further investigation also showed that x and y were always such functions of V that the final result was that obtained by a direct logarithmic plotting.

For example, if the logarithmic plotting leads to $H_f = m\ V^{1.75}$, this method leads to $H_f = x\ V + y\ V^2 = (a\ V^{0.75})\ V + (b\ V^{-0.25})\ V^2 = (a + b)\ V^{1.75}$. If it is admitted that $H_f = m\ V^{1.75}$ represents accurately the relation, it can also be proved mathematically that any attempt to express the relation in two terms will lead to variable coefficients and finally result in the same way as shown above.

A more general expression, $H_f = a\ V + b\ V^2 + c$, is sometimes used. It can be shown, also, that a, b and c will be functions of V. In a number of cases where this form has been used, negative values of c have resulted when a, b and c have been found by least squares. These, surely, are not easily interpreted.

The foregoing investigation shows that the explanation given for the presence of the exponent, 1.75, and which is expressed by the Prony formula, $H_f = x\ V + y\ V^2$, by those who hold to this idea, is questionable. It also shows that all formulas which involve V^2 in any way will also involve in general a coefficient depending on V. The exception consists in the fact that a very few experiments on pipes do show an exponent of 2. As is readily seen, we thus account for the variables f and c in the familiar formulas, $H = 4f\frac{l}{d}\frac{V^2}{2g}$ and $V = C\sqrt{r\,s}$. Of all the forms yet advanced, the only one which will represent the conditions at all accurately is the one the writers have adopted, $H_f = m\ V^n$, and n is to be determined for each series of experiments. It will be seen, of course, that the formula, $V = C\ r^x\ s^y$, is merely a modification of $H_f = m\ V^n$, m being dependent on d.

The writers, for a time, had the idea that the reason for the exponent of V being different from 2 might lie in not distinguishing between the square of the mean velocity and the sum of the squares of the individual velocities throughout the cross-section of the pipe. (They fully recognized, however, the fact that the idea of flow in parallel filaments is merely a theoretical convenience.) They therefore have investigated the question as to what power of V_m will give the same result as $\frac{\Sigma\ V^2}{\pi\ r^2}$. The supposition that the velocity curve is an ellipse, led to results which indicated that their view was correct. The exponent of V_m had a value of 2 for a velocity of 8 ft. per second and decreased for lower velocities. For a velocity of 1 ft. per second, many peculiarities in the values of the exponent were shown similar to those which the present experiments show in the critical-velocity transition stage. However, the best test of theory is experiment, and when a series of Pitot tube traverses was investigated, there was found the experimental fact that the relation, $V_m^2 = \frac{\Sigma\ V^2}{\pi\ r^2}$, holds almost exactly in every case. While proving that the proposed explanation was

incorrect, this fact will doubtless be of value to those who are interested in determining the true form of the velocity curve.

In connection with the value, 1.75, obtained for the exponent on brass pipes, it will doubtless be of interest to mention the fact that Hagen gives the following relation for obtaining the volume of a unit weight of water at any temperature:

$$(t - x)^{1.743} = u\,(G - y)$$

where t is the temperature, x the temperature at the greatest density, G the volume of a unit weight at the temperature t, and y that at the temperature x. The writers would not venture to say that there is any connection between this exponent, 1.743, and the exponent which they obtain for smooth pipes. The coincidence, however, is interesting.

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THEORY OF CENTRIFUGAL PUMPS AND FANS: ANALYSIS OF THEIR ACTION, WITH SUGGESTIONS FOR DESIGNS.

By Elmo G. Harris, M. Am. Soc. C. E.

To be Presented September 16th, 1903.

Introduction.

The writer recently had occasion to look for a satisfactory discussion of the theory of centrifugal pumps, and, not finding the subject introduced at all in most of the books on kindred subjects, he undertook to hunt up some special literature bearing upon it, and was surprised to find that, apparently, the subject of centrifugal pumps had been overlooked or neglected by competent writers on applied mechanics.

That this is true is a matter of no small surprise when the importance of the subject and its attractiveness, theoretically, are considered.

To those who would say that to follow out the conclusions recommended in this paper would lead to unjustifiable refinement in machines applied to rough and temporary use, the answer should be: Knowledge of correct principles does not necessitate extravagant

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and when finally closed, the papers, with discussion in full, will be published in *Transactions*.

refinement, but with it we can simplify and cheapen the machine in such a way as to make the least sacrifice of efficiency; and, further, that there are no apparent reasons why refinement in proportions and workmanship will not yield results fully justifying the extra cost, thus placing the machine in a higher class and extending its use to conditions now considered out of its field.

As a result of this study there are proposed three classes of pumps—Centrifugal, Impulse and Turbine. The necessity of distinguishing purely impulsive action from centrifugal force will be apparent to anyone who follows the discussion, and who has a fair knowledge of mechanics.

In the mathematical equations and formulas introduced in this study there is no attempt to include a factor or term to account for losses by friction, impact, or otherwise. Such losses will occur, of course, but they are of a nature which does not permit of mathematical formulation. The writer thinks it better to present the underlying principles clearly, with the simplest and least possible mathematics, and then interpret the results of experiment by comparison with what ought to occur under perfect conditions. With this in view, the several causes of loss are discussed, and suggestions offered for finding where the greater portion of this loss occurs. (See page 490.)

The writer has found some attempts at mathematical analysis for determining the proportions of a pump that should give maximum efficiency, but thinks that such analyses are a misuse of mathematics, and are apt to put the science in disrepute. Whatever the design of a centrifugal pump (or of an impulse pump), the dynamic principle on which it acts is that of imparting energy to water by giving it a high velocity. Within the machine, the water must be taken from a state of rest (practically), put in motion and brought to rest again, or nearly so. The problem for the designer is then, simply: To put water in motion and stop it again with the least possible friction of water on metal and of water on water—simple in statement, but not simple in accomplishment.

In taking up this study the writer had no intention of going beyond the mathematical analysis, but, was irresistibly led into attempts at designing with a view to reducing friction losses to a minimum. In these designs the novel features introduced are: First, the introduction of air instead of water between the wheel and casing; second, the

support of the wheel (in some designs) by air pressure from below; third, the use of flaring nozzles for checking the velocity of the water as it leaves the propellers, whereby the energy of the velocity can be converted into pressure with the least possible loss; and, fourth, making the discharge adjustable.

With pumps designed and tested according to the conclusions of this study, it will be possible to determine satisfactory coefficients to apply to pumps of a specific class, working under specific conditions.

The proposed modifications, in construction, in proportion, and in operation, make machines so different from anything yet tried that they must be considered as designs evolved from theoretic considerations without the light of experience. Though all the theoretic results may not be realized to a satisfactory degree, the writer believes the study will result in improvements on present practice.

Centrifugal Pumps.

Symbols.—For convenience of reference, the symbols used are collected here. The reader should not be discouraged by the formidable array; they do not all come in at once, and the working formulas will be found to be surprisingly simple. Most of the symbols are also indicated on the diagram, Fig. 1.

r = Radius of outer limit of vanes;

r_1 = Radius of inner limit of vanes;

x = Radius of any intermediate point—a variable;

u = Velocity of revolution of outer limit of vanes;

u_1 = Velocity of revolution of inner limit of vanes = $\frac{r_1}{r}\, u$;

V = Velocity of escaping water, relative to revolving wheel;

V_1 = Velocity of entering water, relative to revolving wheel;

v = Absolute velocity of escaping water;

v_1 = Absolute velocity of water as it enters between vanes;

W = Weight of a cubic unit (foot) of the water (or other liquid);

b = Width of vanes at outer limit = width of circumferential opening or slot through which discharge occurs;

b_1 = Width of vanes at inner limits;

a = Area of discharge slot = $2\,\pi\, r\, b$;

a_1 = Area of entrance to vanes = $2\,\pi\, r_1\, b_1$;

Q = Quantity (cubic feet) of liquid passing (per second);

β = Angle between V and u;

ϑ = Angle of discharge, relative to a tangent to wheel = angle between v and u;

ϕ = Angle between v_1 and $u_1 = 90°$, unless guide vanes be inserted;

h = Head, or lift, above pump;

H = Total effective lift;

k = Initial or entrance head, which is usually suction, or negative head;

p = Pressure head in space between wheel and casing = pressure head in water at instant after escape from wheel.

"Foot-pound-second" units will be used.

Purely Centrifugal Effects.—In this preliminary study the reader should disincumber his mind of the more complicated conditions under which centrifugal pumps actually work. We are now seeking the relations between velocities unaffected by change of pressure. Later, the suction and discharge pressures will be introduced.

Consider a prism of liquid, of unit area and extending between the limits r_1 and r, in a revolving wheel without outlet, as $C\ B$, Fig. 1. The centrifugal force of an elementary disk across this prism, of thickness $d\,x$ and distance x from the axis of revolution, is

$$d\,f = \frac{W\,u^2_x\,d\,x}{g\,x}$$

where u_x is the velocity of revolution at the distance, x, from the center. Thus

$$u_x = \frac{x}{r}\,u,$$

therefore

$$d\,f = \frac{W\,u^2}{g\,r^2}\,x\,d\,x,$$

and the total centrifugal force, f, which is effective at the outer end of this prism, is the integral between the limits, $x = r$ and $x = r_1$.

Hence

$$f = \frac{W\,u^2}{2\,g\,r^2}\,(r^2 - r^2_1) = \frac{W}{2\,g}\,(u^2 - u^2_1), \text{ since } u_1 = \frac{r_1}{r}\,u.$$

This is the pressure on a unit area at the circumference of the wheel, and, evidently, it is independent of the form or cross-section of the arm, $C\ B$. Now, pressure divided by weight gives head. Hence the pressure head against the walls of the pump at the circumference

$$= \frac{u^2 - u^2_1}{2\,g}$$

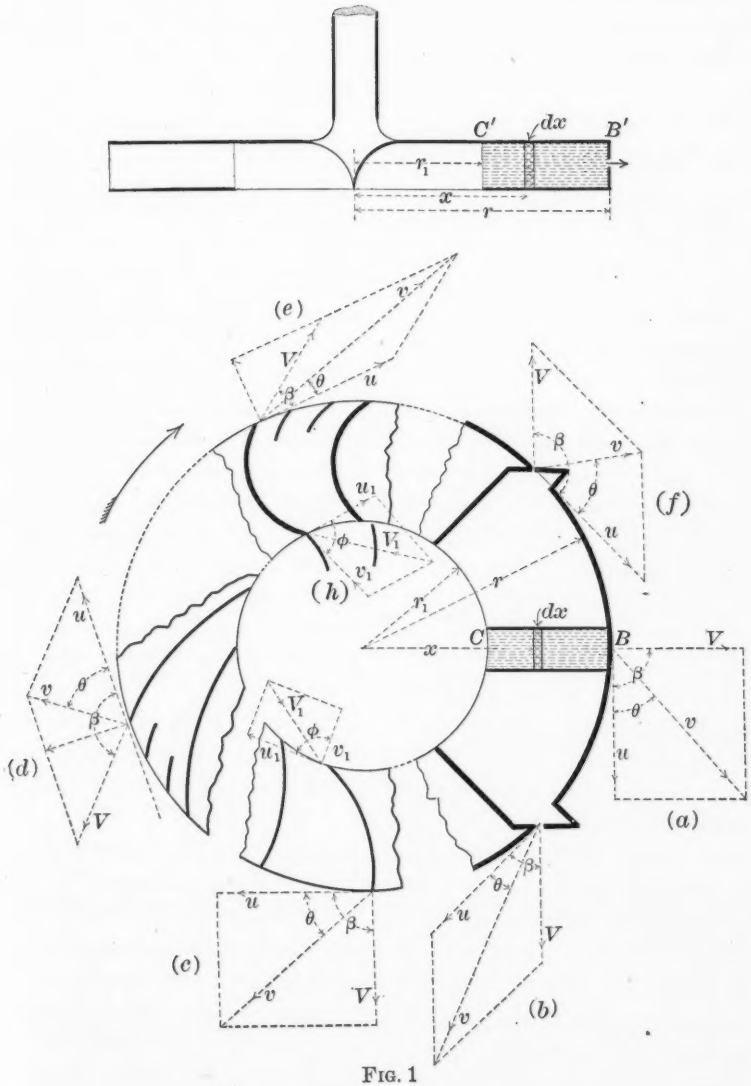


FIG. 1

Now, if an orifice be opened at the circumference, in any direction whatever, and the pressure outside be the same as at the entrance, the velocity of the discharge, relative to the revolving walls of the pump, will be

$$\sqrt{2\,g \times \text{head}},$$

or

$$V^2 = u^2 - u^2_1;$$

but when there is a discharge there must be an initial velocity, V_1, at the entrance, and this must be considered in the final head within the wheel. Thus, the total head at B will now be

$$\frac{V^2_1}{2\,g} + \frac{u^2 - u^2_1}{2\,g};$$

and the velocity of the discharge, relative to the revolving parts, will have the relation

$$V^2 = V^2_1 + u^2 - u^2_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (I)$$

Suppose, now, that $C\,B$ is a radial frictionless tube, open at both ends, and that a particle starts from a state, V_1, relative to the tube, and moves out, without change of pressure, from radius r_1 to r, in obedience to the law of centrifugal force (or acceleration). Its radial acceleration, when distant x from the center, is, by well-known laws of mechanics:

$$\text{Acceleration} = \frac{u^2_x}{x} = \frac{d\,V_x}{d\,t}.$$

Also,

$$V_x = \frac{d\,x}{d\,t}.$$

Therefore,

$$V_x\,d\,V_x = \frac{u^2_x\,d\,x}{x};$$

but, as before,

$$u_x = \frac{x}{r}\,u,$$

(sub x indicating the conditions at the distance, x, from the center.) Therefore,

$$V_x\,d\,V_x = \frac{u^2}{r^2}\,x\,d\,x.$$

Integrating between the limits, V and V_1, on one side, and, r and r_1, on the other, we get

$$V^2 - V^2_1 = u^2 - u^2_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (I)$$

Combined Centrifugal and Impulsive Effects.—In Equation I the reader will probably recognize the well-established relation of veloci-

ties in impulse water-wheels. It is demonstrated in Church's "Notes on Hydraulic Motors," and is there shown to apply to either pumps or motors as long as they act impulsively. It has not been recognized, however, as being applicable to purely centrifugal effects acting statically, as demonstrated on page 482.

The demonstrations of Equation *I* evidently apply to any liquid, and to any gas in which the density may consistently be assumed as unchanged throughout the operations. (See page 520.)

It has now been made apparent that Equation *I* will hold, whether or not the section of the channel between *C* and *B* is constant, and without regard to the direction of the discharge; that is, the discharge may be outward, inward, backward, forward, upward or downward; that it is true whether the accumulation of centrifugal effect appears as pressure alone or as velocity alone, or partly in both; and that it is true for purely impulsive effects and for combined centrifugal and impulsive effects. The formula, therefore, is much more general than has been supposed heretofore.

Absolute Velocity of Discharge.—Having now a formula for computing the velocity of the escape of water from an opening in the perimeter of a wheel, relative to the wheel, its absolute velocity can be obtained from the triangle fixed by u, V, and the included angle, β, Fig. 1.

Thus, evidently, in general,

$$v^2 = V^2 + u^2 + 2\,u\,V\cos.\,\beta \ldots\ldots\ldots\ldots\ldots (II)$$

where β is the angle between V and the forward direction of u. Note that when β exceeds 90°, its cosine is minus. In particular, when $\beta = 90°$, or the vanes are radial at the outer end and $p = p_1$, then

$$v^2 = V^2 + u^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (III)$$

It is well, here, to call attention to the effect that the angle, β, has on v. Notice that u and V are constant in all the several diagrams of Fig. 1, yet v is very different in the several cases. Now, if the reader will remember that the head varies with the square of the velocity he will see that the theoretically possible head, or lift, in Case (*e*) is about six times as great as in Case (*d*). (See also page 494.)

Pressure Head in Discharge and Entrance.—The foregoing formulas for V and v are derived on the assumption that the water is discharged into a medium in which the pressure is the same as in that from which the water entered the wheel, as, for instance, atmospheric pressure

within the entrance and outside of the wheel. This, evidently, is not a condition under which centrifugal pumps work ordinarily. Usually, there is "suction" inside the wheel, and, it is generally (erroneously) supposed, a pressure nearly equivalent to the remaining lift, opposing the discharge. Some relations involving this phase of the subject are as follows. See Fig. 2.

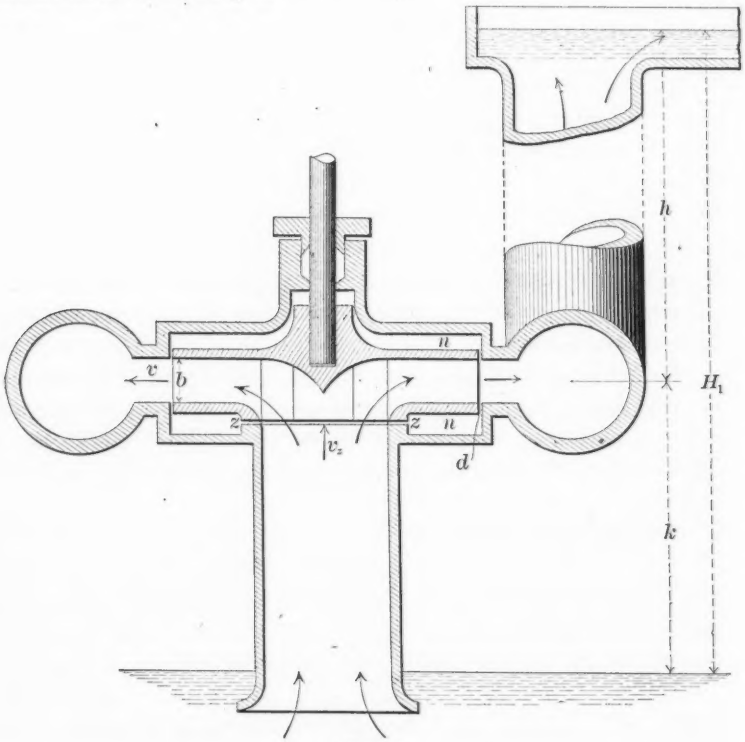


FIG. 2.

Let p_1 = pressure head at entrance of vanes, where velocity is v_1. Then

$$k = p_1 + \frac{v_1^2}{2g}.$$

Let p = pressure head in water immediately after escaping from wheel, where velocity is v, that is, at the joint, d, Fig. 2.

Then remember that whatever head, H, or lift, the wheel gives to the water, it is accomplished while passing out between the vanes.

Remember, also, that the total head in the water immediately after escaping from the wheel (that is at the joint, d) must equal the remaining lift, h.

Heads above the wheel are plus, those below are minus.

Then,

$$k + H = \frac{v^2}{2g} + p = h,$$

by the law of conservation of energy, or

$$\frac{v^2}{2g} = h - p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (IV)$$

and

$$H = \frac{v^2}{2g} + p - k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (V)$$

If, in Equation IV, p = zero, or atmospheric pressure, then $\frac{v^2}{2g} = h$; and if $p = k$, in quantity and in sign, then $\frac{v^2}{2g} = H$; which are evidently correct.

Note that p cannot equal h, as is usually supposed, for then v would be zero, and there would be no discharge.

Note that the signs in Equations IV and V are general, but that p and k may be, in themselves, plus or minus. Care must be taken to observe this, or confusion will result.

If possible, in practice, p_1 should equal p, for then there will be no tendency to leak at the joint, z. (See page 496.)

Notice that the pressure, p, at the joint, d, will extend throughout the spaces, n, n, between the wheel and the casing.

The question now turns on this unknown quantity, p. That it is a factor we cannot ignore, is evident, for it affects the volume of discharge, and it renders useless the formulas thus far given, unless it can be determined and controlled. (See page 490.)

The processes by which Equation I is reached are not applicable unless $p = p_1$, and has the same sign, but, fortunately, the method used on page 482 can be extended to meet the present needs.

When there are no guide vanes (and this will be the common condition), the absolute velocity of approach, v_1, will be radial, as at C, Fig. 1. In that case $V^2_1 = v^2_1 + u^2_1$.

Inserting this in Equation I, we get

$$V^2 = v^2_1 + u^2.$$

Hence the head, relative to the wheel, within itself, at the perimeter,

due to centrifugal effects, independent of pressures before entering, is $\frac{v_1^2}{2g} + \frac{u^2}{2g}$. Now, if the total head at the entrance is k, the pressure head there will be $k - \frac{v_1^2}{2g}$, and the total head within the wheel at the perimeter is

$$k - \frac{v_1^2}{2g} + \frac{v_1^2}{2g} + \frac{u^2}{2g} = k + \frac{u^2}{2g}.$$

Then, if the pressure outside is p, the velocity of escape through an orifice at the perimeter in any direction is

$$V^2 = 2g\left(k + \frac{u^2}{2g} - p\right) = u^2 + 2g(k - p) \ldots\ldots (VI)$$

Note that k and p may be either positive or negative in themselves and in numerical calculations the proper sign must go with them. For instance, if they are both negative (the common condition), their signs will be reversed in Equations *IV*, *V* and *VI*.

In Equation *VI* we have a formula for V (the relative velocity) that can be used with confidence, provided we know p. More on this subject will be found on pages 498 to 501.

From Equations *II*, *V* and *VI* we can get

$$g H = u^2 + u V \cos. \beta \ldots\ldots\ldots\ldots\ldots (VII)$$

or,

$$g H = u^2, \text{ when } \beta = 90°.$$

Which shows that H is independent of k and p. It is interesting to note that $\frac{u^2}{2g}$ is usually stated to be the maximum theoretic lift, regardless of the angle, β (see page 490).

Independent Derivation of Chief Formulas.—The following independent demonstrations are interesting, and will strengthen our confidence in the conclusions otherwise reached.

If, in Fig. 1, the vanes take up the water from a state of absolute rest and discharge it at the perimeter, the whole work done by the wheel can be expressed in terms of the reaction of the escaping water on the wheel. This reaction, by well-known laws of hydro-mechanics, is $\frac{W v}{g}$, and the component opposed to the motion is $\frac{W v}{g} \cos. \theta$. Then the work done by the wheel in overcoming this reaction is $\frac{W v}{g} \cos. \theta\ u$. Then, assuming the pressure opposing the discharge

to be the same as before admission, the energy in the water after escape is $\frac{W v^2}{2 g}$.

Hence,

$$\frac{W v^2}{2 g} = \frac{W}{g} u v \cos. \theta.$$

or,

$$v = 2 u \cos. \theta.$$

This being true, a glance at the trigonometrical relations in Fig. 1 will show that $v = u$, and $\theta = \frac{\beta}{2}$.

The assumption, that the water is at rest until caught up by the vanes, is not correct when the water is passing through. To get an equation meeting this condition we have only to remember that the static pressures inside and outside a wheel, though different, cannot directly aid or resist its revolution, and that, in pumps, we may assume the velocity of approach, v_1, to be caused by the pump, and, therefore, its effect on the wheel is not to be considered, it being only a preliminary incident to the final discharge. Hence, the work against the reaction of the discharged water will always be the total work done by the wheel. Then, by the law of the conservation of energy, the following equation must hold:

$$W k + \frac{W v}{g} u \cos. \theta = \frac{W v^2}{2 g} + p W = W h \ldots\ldots (a)$$

Hence,

$$2 u v \cos. \theta = v^2 + 2 g (p - k).$$

Now, insert the value of $2 u v \cos. \theta$, from the trigonometrical relation, $V^2 = u^2 + v^2 - 2 u v \cos. \theta$, and the equation reduces to

$$V^2 = u^2 + 2 g (k - p) \ldots\ldots\ldots\ldots\ldots (VI)$$

which is identical with Equation *VI*, on page 488.

From Equation a we have $H = \frac{v^2}{2 g} + (p - k)$, since $H = h - k$ (see Fig. 2), and, by trigonometry, $v^2 = V^2 + u^2 + 2 u V \cos. \beta$. Now substitute this and the value of V^2 from Equation *VI* and we get

$$H = \frac{u^2 + u V \cos. \beta}{g} \ldots\ldots\ldots\ldots\ldots (VII)$$

as on page 488.

It is remarkable, and to the writer quite unexpected, that Equations *VI* and *VII* show no factor involving the radial depths of the propellers, that is, the relation between r and r_1; but careful considera-

tion of all the conditions involved will make it clear that such should be the case. On page 484 the formula, $V^2 = u^2 - u^2_1$, may be written $V^2 = u^2\left(1 - \frac{r^2_1}{r^2}\right)$, since $u_1 = \frac{r_1}{r}\, u$. Here, then, we find the relation between r_1 and r involved, and the analysis there given shows that it must be; but, in that case, there is, to that point, assumed no movement of water through the pump. When water flows into the pump it must be caught up by the propellers, and the velocity suddenly changed from v_1 to $\sqrt{v^2_1 + u^2_1}$. Thus it is seen that the pump must do work on the water in the act of picking it up; and this is independent of the static head (considered relatively to the wheel) imparted between the limits r_1 and r. Without adhering to a strictly correct use of mechanical terms, perhaps, we may say that with a fixed r and u the head imparted by the static effect of centrifugal force decreases as r_1 increases, while the work done by impact (or reaction) in taking up the inflowing water increases with r_1; the sum of the effects in imparting energy to the departing water being constant when r_1 only varies.

Volume of Discharge.—Referring to Fig. 1, it is seen that the radial component of V is $V \sin. \beta = v \sin. \delta$, hence the volume of discharge is

$$Q = a\, V \sin. \beta = 2\, \pi\, r\, b \sin. \beta\, V. \ldots\ldots\ldots (VIII)$$

assuming a continuous opening or slot, of width, b, around the perimeter.

Evidently, the entrance to the vanes or propellers must be proportioned to comply with

$$Q = 2\, \pi\, r_1\, b_1\, v_1 \sin. \phi. \ldots\ldots\ldots\ldots\ldots (IX)$$

$v_1 \sin. \phi$ is the radial component of the velocity of the water as it enters between the vanes. This will usually be assumed to be between 10 and 20 ft. Unless guide vanes are inserted, as at (h), Fig. 1, and (b), Fig. 15, the angle, ϕ, will be 90°, and Equation *IX* will become

$$Q = 2\, \pi\, r_1\, b_1\, v_1. \ldots\ldots\ldots\ldots\ldots (IXa)$$

Present Practice, in the Light of the Preceding.—The foregoing discussion, with the resulting equations, will give light on matters not heretofore generally understood (judging from correspondence, the contents of trade circulars, and the proportions of pumps as built). For instance, it is a common statement that the theoretic lift depends only on the velocity, u, of the outer limit of the propellers, and that the theoretic lift is $\frac{u^2}{2\, g}$. Equation *VI* shows this to be doubly in error.

True, after a wheel is built, u is the only variable affecting the lift, but, in the intelligent design of a pump, the angle, β, is an important factor.

Some writers, whose opinions are apt to be accepted without question, state that when the propellers are curved backward, as in Fig. 5, there is, in addition to purely centrifugal effects, an outward "shove," or impulse, given to the water, as it escapes, by the tips of the propellers. In making this claim, they probably forget that the water is revolving with the propellers before it reaches the end. Evidently, when the water is moving with the propeller no impulsive action can occur between them. If the outer few inches of the propellers came in contact with still water, the effect claimed would occur, and the result would be an impulse pump.

The writer can find no theoretic reason for curving the propellers backward, but rather the reverse. (See page 485.)

In several published articles which the writer has examined, prominence is given to the test for the effect of curvature of the vanes, the test being made by running the pump without discharge and measuring the resulting pressure or head by a gauge or stand-pipe, thus getting the relation between the peripheral speed and the head for differently curved vanes.* In the light of the discussion on page 482, this scheme is fallacious, for, as the propellers, of whatever form, revolve, friction will impart the motion of the liquid to that within the inner limits of the vanes, and in a few moments all the liquid, from the center out, will be revolving with the vanes. Then, as shown previously, the pressure head at the perimeter will be

$$\frac{u^2}{2g} - \frac{u_1^2}{2g} = \frac{u^2}{2g},$$

since u_1 is zero. The curve of the vanes would have nothing to do with it. Where a discharge occurs, the curvature affects the head, but not otherwise. That varying results were actually gotten, must have been due to some circulation through the open joints, d and z, around the discharge and intake.

Unfortunately, the above-mentioned experiments, as misinterpreted, have apparently verified the very common supposition that the theoretic lift of a centrifugal pump is $\frac{u^2}{2g}$. There seems to be almost universal confusion and error concerning this, and universal neglect to consider correctly the pressure at the open joint, d. Correct

* *Engineering News*, August 9th, 1900; and Richards' "Centrifugal Pumps," p. 27.

equations bearing on these points—Equations IV to VII—have been given, but, to clear up the confusion, let us recall the fundamental principle in hydraulics, that "total head equals velocity head plus pressure head," and apply it to the water passing the joint, d, after it has left the propellers. Then, using the notation elsewhere applied, the head in the water passing d is $\frac{v^2}{2g} + p$, and, neglecting friction, this must equal the remaining lift, h, or, $h = \frac{v^2}{2g} + p$.

Now, v is always greater than u, except when no discharge occurs. Evidently, then, we cannot consistently assume that the lift above the pump is $\frac{u^2}{2g}$, and that the pressure head, p, at the discharge is that due to the same lift, for that would be assuming, by the equation above, that $h = 2h$ (or more when β is less than 90°).

Suppose the pump is revolving without discharge, then the equation becomes $h = \frac{u^2}{2g} + p$, but, on measuring the head in a stand-pipe we would find it $= \frac{u^2}{2g}$, only. Still, the equation is correct. The explanation is that the velocity head, $\frac{u^2}{2g}$, in the water is not transformed into pressure head. When a discharge occurs the water passing out must lose its velocity, and, theoretically, should gain in pressure correspondingly. This subject is discussed further on page 501.

If, in Equation V, viz., $k + H = \frac{v^2}{2g} + p = h$, we substitute the value of H from Equation VII, we have

$$p = \frac{u^2 + u\,V \cos.\,\beta}{g} - \frac{v^2}{2g} + k.$$

Now, in centrifugal pumps, as usually constructed and operated, the absolute velocity, v, is but little greater than the peripheral velocity, u. Hence, for the purpose of illustration, we will assume $u = v$. Then the above equation becomes:

$$p = \frac{u^2}{2g} + \frac{u\,V \cos.\,\beta}{g} + k.$$

To show by example what p would be in an ordinary pump, assume

$$u = 50,\ V = 5,\ \beta = 120 \text{ (or cos. } \beta = -0.5), \text{ and } k = -10.$$

Then, by Equation VII, $H = 74$, and therefore $h = 64$, and, by the above equation, $p = 25$.

One cause which adds to the confusion in this matter is that the efficiency of such pumps is not far from one-half, thus making the actual lift attained about one-half the theoretic lift, or

$$H = \frac{u^2 + u\ V \cos.\ \beta}{2\,g},$$

instead of

$$H = \frac{u^2 + u\ V \cos.\ \beta}{g}.$$

It is very important that the pressure, p, be measured in any test, for by its aid we can interpret results much more intelligently than has been done in the past. For instance: The lift, h, above the pump should equal $\frac{v^2}{2\,g} + p$, and the deficiency shows what is lost after the water passes the joint, d. Thus we may determine where the greatest loss occurs.

Balancing.—The much-discussed subject of balancing centrifugal pumps should be studied in the light of the preceding remarks.*

The assumption that the pressure head under the propeller disk is that due to the lift above the wheel is certainly wrong. The problem is different in every design, and, in any design, the proportions affect the results.

The following special case is interesting: The wheel, $A\ A$, Fig. 3, revolves over the fixed plane, $B\ B$, with peripheral velocity, u. The space, $C\ C$, is filled with water which revolves with A, and, by virtue of its centrifugal force, exerts a pressure downward on B and upward on A. What is the force tending to lift A?

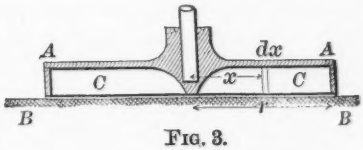


FIG. 3.

The head, at the distance, x, from the axis, is $\frac{u_x^2}{2\,g}$, where $u_x = \frac{x}{r}\,u$. The upward pressure on a ring, of radius, x, and radial width, $d\,x$, is

$$d\,p = 2\,\pi\,x\,d\,x \times W \frac{u^2}{2\,g}\frac{x^2}{r^2} = \pi\,\frac{W\,u^2}{g\,r^2}\,x^3\,d\,x.$$

Integrating between $x = r$ and $x = 0$, we get

$$P = \frac{\pi\,r^2}{2} \times W \frac{u^2}{2\,g}$$

which is half the pressure on a circle, of radius r, due to a head of $\frac{u^2}{2\,g}$. This uplift is doubled in some designs proposed later herein.

* *Engineering News*, Vol. 38, p. 75.

Form and Depth of Vanes.—According to the mathematical analysis on page 487, the ratio, $\frac{r_1}{r}$, does not affect the head under which the pump can work. Notwithstanding that, the ratio should be selected with care, in order that the pump may be otherwise proportioned conveniently and efficiently. In the light of the preceding, there are no grounds for making the outer radius, r, two or three times the inner radius, r_1, as seems to be the common practice.

Some builders state that every particle of water should pass around with the wheel at least once, and most of them accept that idea (judging by the proportions of their pumps). This is probably due to some notion that full centrifugal effect is not produced until the particle has made one revolution around the axis. The seriousness of this error in pumps, as heretofore designed, lies in the fact that, in proportioning them accordingly, the area of the surface over which the water moves at a high velocity is made much greater than necessary. While there are lacking experimental data on the friction of water passing over smooth surfaces at such velocities as occur in pumps, such facts as are known point to very serious loss due to this cause.

It is the writer's opinion that the less the radial depth of the propellers the better; provided that every particle of water be brought to one condition, as to pressure and velocity, before escaping from the wheel; and that the inner tips of the propellers (vanes) be set to part the approaching water without shock. It may be noted here that if the vanes be made short it becomes impracticable to make β much less than 90°, except in the special design shown in Fig. 11.

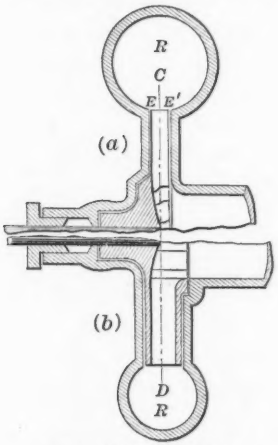
It is evident that the inner terminus of the vane is immaterial, theoretically, provided it has the proper forward inclination, as specified above. The simplest construction is that shown in Fig. 11, where the vanes are sheared off at their inner limits parallel to the axis and reaching only to the periphery of the circular inlet. If they extend to the center, as in Fig. 6, the forward inclination of the edges should vary from nothing at the center to the maximum at the outer limit of the inlet.

Influence of Discharge Passages.—Thus far, this study has been confined to the means of propulsion and its effects on the fluid. The influence of the passage which conducts the liquid from the perimeter of the propelling wheel to the final straight discharge pipe will now

be studied. Here, conclusions even more interesting than in what has preceded will be found.

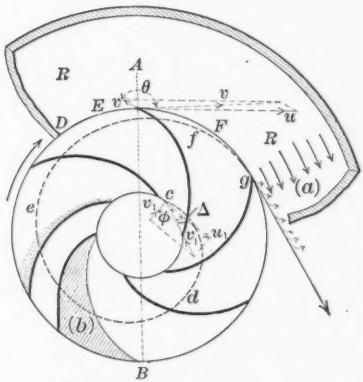
We can probably best lead up to, and understand, this part of the subject by following out the action in a pump of such proportions as are known to be common. Then modifications can be suggested.

The following data are taken from a published test of a pump made by one of the best manufacturers (unimportant fractions being omitted) (see Figs. 4 and 5):



SECTION *A-B* OF FIG. 5.

FIG. 4.



SECTION *C-D* OF FIG. 4

FIG. 5.

r = 4 ins.;

r_1 = 12 ins.;

β = 153 degrees; therefore, cos. β = — 0.89;

u = 57 ft. per second;

Q = 3 cu. ft. per second;

k = — 21 ft.;

H = 35 ft., as measured.

The width of the propellers is not given, but it will be assumed to be 2 ins., which will make the area of the circular inlet just equal to the area of the inlet between the propellers, that is, the water has a constant velocity of 8.6 ft. per second as it enters the wheel and passes in between the propellers.

The angle, Δ, between V_1 and u_1 is not given, but it should be 24° 15′ in order that the water may glide in without shock or break

(see Fig. 7). In such wheels it is common to make the propellers of constant width. Assuming this to be so, the outlet area will be three times as great as the inlet, and the radial component of the discharge velocity, therefore, will be one-third of 8.6, or nearly 2.9. Whence, from Fig. 1, evidently

$$V = \frac{2.9}{\text{sin. } \beta} = 6.8.$$

Then, by Equation *VII*, remembering that cos. β is minus, we get $H = 90$. As the recorded total lift was 35 ft., this would show an efficiency of 40 per cent. This does not agree with the report. However, some of the proportions have been assumed, and a glance at Fig. 5 will show the triangle involving V, u and v in a form unfavorable to accuracy.

From Equation *II*, we find $v = 51$. Then, by Equation *IV*, we have $h - p = 41$, and since $H = h - k$, and $k = -21$, h must be 69. This makes $p = 28$.

The reader must bear in mind that these are the theoretically perfect results. We know, from the results of tests, that a large part of the energy is lost somewhere.

Causes of Loss of Energy.—Now, let us discover the chief causes of loss of energy. When understood, we may then find means of avoiding, or, at least, reducing them.

(*a*)—The inner tips of the vanes should point opposite to the relative motion of the incoming water, or tan. $\phi = \frac{v_1}{u_1}$, where no guide vanes are inserted (and this will, doubtless, be the common practice), Fig. 7 (*a*). To fulfill this condition, it is evident that the discharge must vary directly with the velocity of revolution. Hair-splitting precision in this matter is not essential nor practicable, but a gross neglect will result in shock at the point of the vane and eddies just behind it. In extreme cases of neglect of this point a vacuum may occur at about (*c*), Fig. 7, especially where the suction, k, is large, Fig. 6 (*b*).

(*b*)—From the example above, we note that the radial velocity at the entrance between the vanes is 8.6 and at the discharge 2.9, the average being 5.7, while the outer tip of the vane has a velocity of 57.0. Under these conditions, the wheel makes a little more than one revolution while a particle of water passes from the inner to the outer

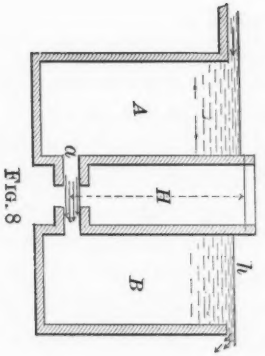


Fig. 8

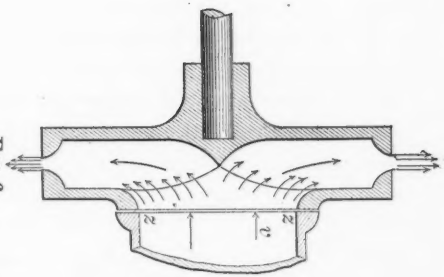


Fig. 6

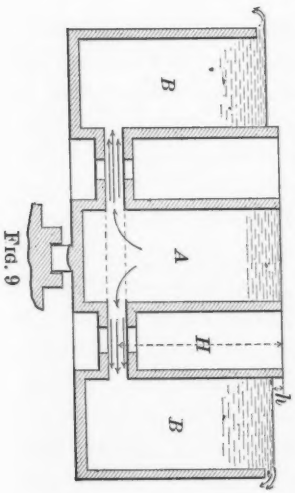


Fig. 9

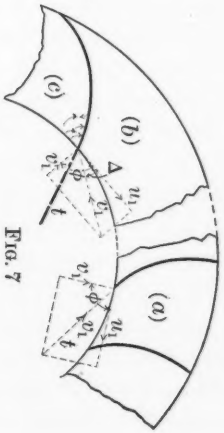


Fig. 7

limit of the vanes. During this time the water slips against the fixed sides of the casing, a distance of more than 6 ft., with a (relative) velocity varying between 19 and 57 ft. per second. This is true whether the propellers be of the open type, Fig. 4 (*a*), or the inclosed type, Fig. 4 (*b*); for, in the latter, the water surrounding the runner must either slip, relative to the runner, or relative to the fixed casing, or both. This is probably one of the chief causes of loss.

(*c*)—In the example taken we found $u = 57$. Now, if we knew all the dimensions we could compute the mean velocity in the volute, *R*, Fig. 5. It should not, and does not in practice, exceed 10 ft.

Then we would have, along the surface, *E E'*, or *D E F*, one body of water moving against another with a relative velocity of 47 ft. or more. If the wheel is of the "hollow-arm" type, that is, part of the wheel is solid, as at (*b*), Fig. 4, the last two causes will be even more serious. Here must be another important cause of loss. It is sometimes called the "drag" at the tip of the propellers. See Fig. 4 (*a*).

(*d*)—Lastly: When the section of a flowing stream is suddenly enlarged, as at *E E'*, some loss occurs.*

We have thus followed the water through the wheel, have noted the causes of loss of work, and have, to some extent, indicated the degree of importance of each. They are not of a nature that can be analyzed mathematically, but are none the less real. It should be mentioned, perhaps, that these losses depend on the construction (or design) of the wheel, its speed, discharge, etc.

The remedies for losses (*a*) and (*b*) are apparent. That under (*c*) can be reduced by decreasing the radial length of the vanes and by curving the vanes forward, thereby reducing the necessary speed. See page 490.

Losses (*d*) and (*c*) can be avoided by means now to be described.

The radical departure here proposed, in the construction of centrifugal pumps, depends chiefly on two principles, both well known, but neither, to the writer's knowledge, having been applied in this connection.†

The discharge from the vessel, *A*, Fig. 8, will enter *B* as long as the drop, *h*, is equal to the losses by friction, etc.; and the velocity of this discharge is dependent on the head *H*. Thus, without increasing the area of the orifice, *a*, or the effective head, *h*, we can increase the

*Cyclop. Brit., Vol. 12, Art. 32, p. 469.
†Cyclop. Brit., Vol. 12, Art. 28, p. 467, Fig. 36, reproduced here in Fig. 8.

discharge indefinitely by increasing H. Now, suppose the vessel, B, to be continuous around A, and that both orifices are continuous annular slots, as in Fig. 9. Under this condition, the vessel, A, can be revolved about its vertical axis without interfering with the discharge or its reception in B. This hints at the application of the principle to increase the flow from centrifugal pumps. But a difficulty yet stands in the way: If the head in A is due to centrifugal effect, and that in B is the resulting lift, there will be closely limited relations between the rate of revolution, lift, etc., which, if changed, will result either in water not entering B (when the speed is too low), or in air entering with the water (when the speed is too high). To control this better, and for other reasons, apparent later, we will apply the second principle, which is that of the Sprengel Pump, or aspirator. See Fig. 10. The outwardly-flaring nozzle placed on the vessel, B, will cause a suction at its least section when the energy of the discharge from A is greater than necessary to lift the water in B, or against the required head.

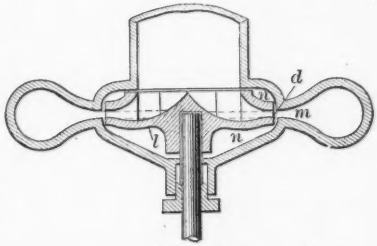


FIG. 10.

This suction will tend to exhaust the air from the space, n, surrounding the wheel, l. As the exhaustion increases (or the pressure head, p, drops) the discharge will increase until a state of equilibrium is reached. Then the wheel will turn in partial vacuum instead of in water, there being no leakage of air inward nor of water outward, though a clear joint is left between the wheel and the receiving nozzle, m. The high velocity of discharge will give an absolute direction of discharge a little less than 45° outward from a tangent when $\beta = 90$ degrees. The flaring receiving nozzle, m, will reduce this velocity gradually without serious loss of energy. Notice that all "thrashing" of water by impellers, and all "drag" of rapidly moving water against that which is comparatively still, are eliminated.

Here, then, we have a means of avoiding entirely the losses (*c*), (*d*), and (*e*) on page 498. In their place will occur whatever loss is unavoidable in the nozzle, m. The writer knows, from tests made by himself, that this can be reduced to 15 per cent. See page 518. In such a wheel the area of the passage through the wheel should be as large as

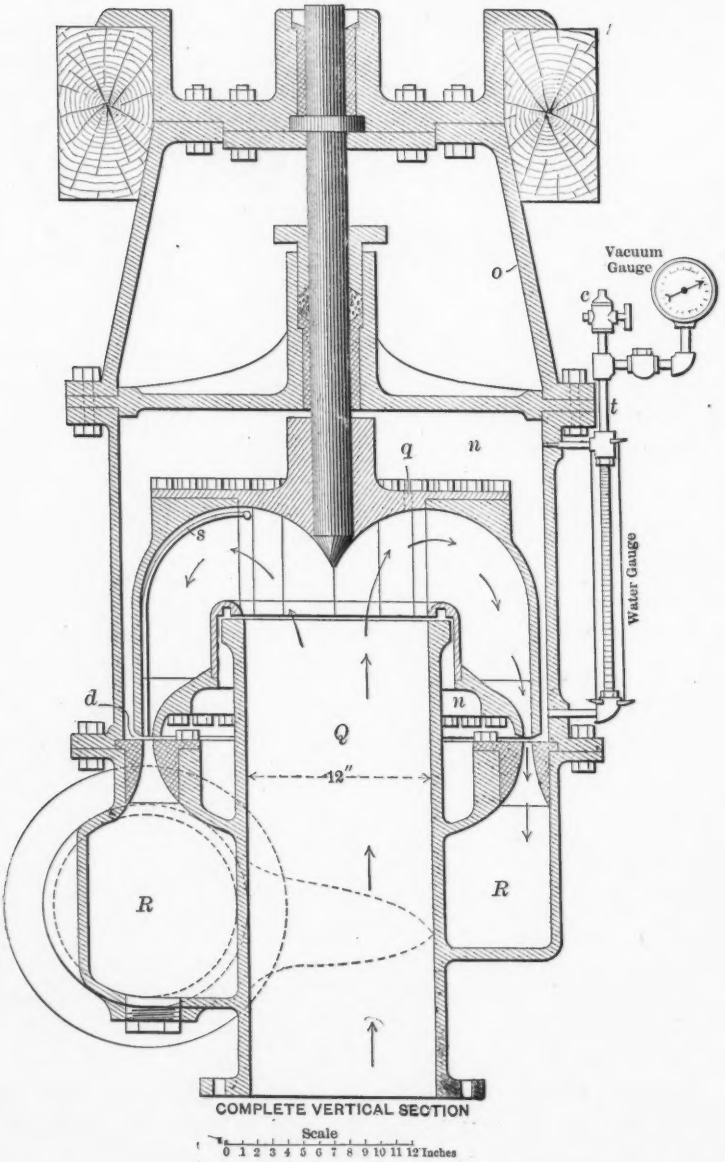

Vacuum Gauge
o
c
t
q
n
s
Water Gauge
d
n
Q
12″
R
R
COMPLETE VERTICAL SECTION
Scale
0 1 2 3 4 5 6 7 8 9 10 11 12 Inches

FIG. 11.

convenient, to reduce velocity, and thereby friction loss, inside the wheel, and to give all particles time to come to one condition of pressure and velocity. The contraction for the outlet should be a sharp curve near the periphery. Note that the only sliding friction of the water against the wheel occurs in the radial movement of the water relative to the wheel. It matters not how many times the water goes around within the wheel.

The suction or minus head, p, in the space, n, probably cannot be specified until some further experimenting is done. (In some experiments of the writer with straight nozzles it was nearly 20 ins. of mercury.)

Fig. 11 presents the writer's idea of a construction well suited to secure the conditions desired, as pointed out in the preceding paragraphs.

The design shown in Fig. 11 has the further advantage that the reaction of the discharge can support the weight of the wheel partly or entirely. It has also the advantage of compactness, and the discharging and receiving nozzles can be more easily kept opposite.

Starting.—On page 491 it is shown that when a centrifugal pump is revolving without discharging, the greatest pressure head it can produce is $\frac{u^2}{2g}$, while, by Equation *VII*, the lift, when in operation, is found to be $H = \frac{u^2 + u V \cos. \beta}{g}$. Now, since the writer recommends that cos. β be always positive, or zero, it is evident that a wheel cannot start a discharge when under back pressure, from the maximum lift under which it can work after being started. This difficulty is overcome readily by putting a check-valve in the discharge, and between that and the pump a valved branch through which the discharge can be made temporarily under low head. Then, when the pump gets its normal speed and discharge, the starting valve, f, Fig. 12, can be closed gradually, and the flow will be directed into the main pipe.

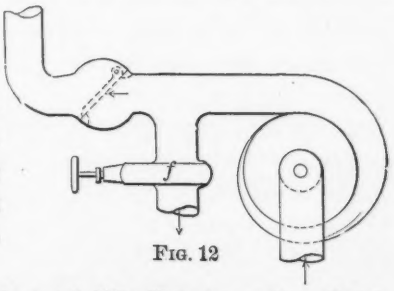


FIG. 12

In case the greater part of the total lift, H, is in suction, that is, when k is negative and nearly equal to H, numerically, the branch

pipe carrying the valve, f, should descend into the sump, or source from which the water is taken. That this is necessary will appear from an examination of Equations *VI* and *VII*.

$$V^2 = u^2 + 2\,g\,(k - p)$$

and

$$g\,H = u^2,\ (\beta \text{ assumed } 90^\circ).$$

From these we get

$$V^2 = g\,(H + 2\,k - 2\,p).$$

Now, if k is negative and greater than half of H, and p is zero or any positive quantity, the second member becomes negative, or V indeterminate. Evidently, when k is negative and nearly equal to H, p must also be negative and greater than half of H. The arrangement specified above will insure these conditions at starting. After starting, p can be controlled through the cock, c, Fig. 11.

In Fig. 11, a small tube, s, starts from within the inner limits of the vanes and extends out to the discharge. The necessity and duty of these tubes will be apparent from the following:

If a vessel containing water and air revolves rapidly, centrifugal force will separate the two (independently of gravity), the lighter air being forced to collect about the axis of revolution. This will occur should air by any means get into any of the centrifugal pumps proportioned as in Fig. 11 (where the outlet is very much contracted as compared with the area of the passage through the wheel). The above will not hold, however, in a tube of constant cross-section leading away from the axis of revolution and open at the outer end, as the tube, s. On the contrary, there will be, in such a tube, a suction throughout its length due to the accelerated outward velocity of whatever water or air may be in the tube. This suction, being greatest at the inner end of the tube, will take out all bubbles that would otherwise collect about the center of the wheel and interfere with the action.

A close analogy to the above principle may be found in the suction caused by water flowing down an open vertical tube.

If, in practice, the suction, p, in the space, n, is found greater than k, the same purpose could be accomplished by a small hole in the top of the wheel, as at q, Fig. 11.

Method of Proportioning.—The formulas necessary in designing are:

$$V^2 = u^2 + 2\,g\,(k - p) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (VI)$$

$$H = \frac{u^2 + u\ V \cos.\ \beta}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (VII)$$

$$Q = 2\,\pi\,r\,b\ V \sin.\ \beta \ldots\ldots\ldots\ldots\ldots\ldots (VIII)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \sin.\ \phi \ldots\ldots\ldots\ldots\ldots\ldots \quad (IX)$$

These must be applied intelligently in order to work out the dimensions of the principal parts of a pump. The fixed conditions will usually be H, Q and k; p can be assumed with practical accuracy after some experimenting. For reasons heretofore given (pages 488 and 496), it ought to be, and probably will be, nearly equal to k. Then, until experiments give more reliable information, we may assume $p = k$. For reasons of simplicity and economy of construction, it is probable that the outer tip of the propelling vanes will be made radial, that is, $\beta = 90$ degrees. For the same reason, it is probable that the guide vanes at the entrance will be omitted, that is, $\phi = 90$ degrees.

With these simplifications the several formulas become:

$$V^2 = u^2 + 2\,g\,(k - p) \ldots\ldots\ldots\ldots\ldots\ldots (VI)$$

$$H = \frac{u^2}{g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (VIIa)$$

$$Q = 2\,\pi\,r\,b\,V \ldots\ldots\ldots\ldots\ldots\ldots\ldots (VIIIa)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \ldots\ldots\ldots\ldots\ldots\ldots (IXa)$$

The working out of proper proportions will now seem simple, but a difficulty will be found, in that b will in many cases be embarrassingly small. This fact alone will prevent the application of such pumps where the lift is great and the quantity small. (Modifications to overcome this difficulty are described on page 514.)

The most rational order of proceeding will be to assume a velocity through the intake channel, v_2, and also the velocity of entrance to the vane, v_1. These may both be taken safely at 10 ft. per second. As soon as the velocity through the intake is fixed, r_1 becomes known, from the condition, $\pi\ r^2_1 \times$ velocity $= Q$, for a single intake; or $2\,\pi\,r^2_1 \times$ velocity $= Q$, for a double intake. We can then find b_1 from Equation *IX*. Next, assume $\frac{r_1}{r}$ between 0.50 and 0.75. This will fix r. u will be found from Equation *VII*, V (relative velocity), from Equation *VI*, and b from Equation *VIII*.

Before leaving the subject of centrifugal pumps, attention should be called to the advantage of making both the discharging and receiving nozzles detachable. Then, with a few standard sizes of wheels

and casings, nozzles can be attached, to meet any ordinary requirements, thus reducing the cost of manufacture; it is further desirable, on account of the liability of the nozzle to wear, especially if the water is at all gritty.

Impulse Pumps.

The name "impulse pump" is given by the writer to that class of rotary pumps in which the energy is imparted to the water by impulsive action. They must be placed in a class by themselves, for, though resembling centrifugal pumps in some points of construction and in their mathematical formulas, they are quite different in principle, and present another set of problems for solution. It is sometimes said that such pumps are the reverse of the impulse water-wheel. That is true, as to principle, but an impulse water-wheel turned backward would not make a pump.

To show that the action is independent of centrifugal force, suppose the vanes, *W W*, Figs. 13 and 14, to move forward in a straight line. Then there could be no centrifugal force, and yet the water would be caught up and thrown out at the upper edge with a velocity, *v*, as shown in the figures.

In practice, the vanes must be placed on the periphery of a wheel, Fig. 15, and, if the discharge is outward, it is apt to be mistaken for a centrifugal pump. In fact, in that case, there will unavoidably be some centrifugal effect; but, if proportioned to get the best results from impulsive effect, the centrifugal effect will be relatively small. If the vanes are set to move the water parallel to the axis, as in Fig. 16, there can be no centrifugal effects. The vanes may even be set to throw the water inward toward the axis.

Careful attention should be given to the following distinctive conditions in purely impulse pumps, viz.: There should be no change of pressure in the fluid as it passes out between the vanes, the energy imparted to the fluid appearing as increase of velocity alone. That this is true will appear on inspection of Fig. 13 (*b*), where the vane is only partly filled, the water being under atmospheric pressure throughout; yet as much energy will be imparted to the water in Case (*b*) as when the space between the vanes is filled. To meet this condition requires that the area of the passage between the vanes be proportioned carefully throughout. This is not necessary in centrifugal

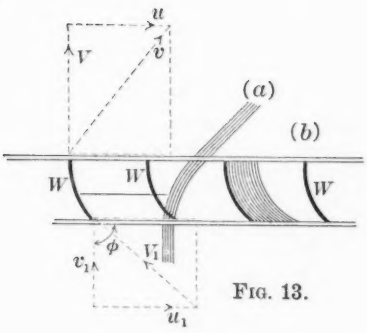


FIG. 13.

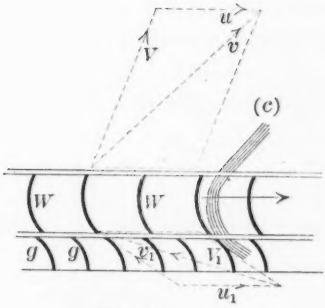


FIG. 14.

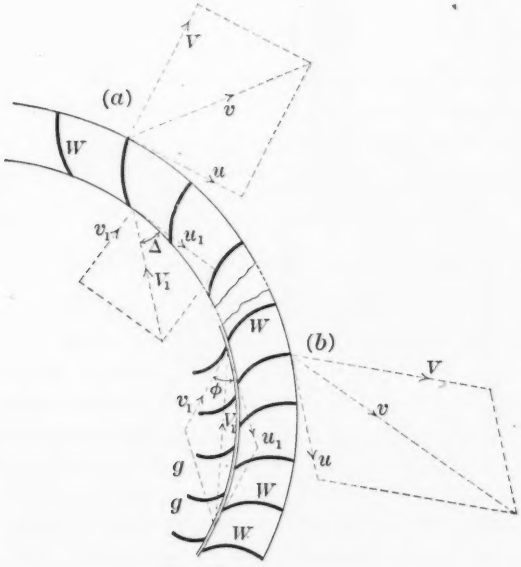


FIG. 15.

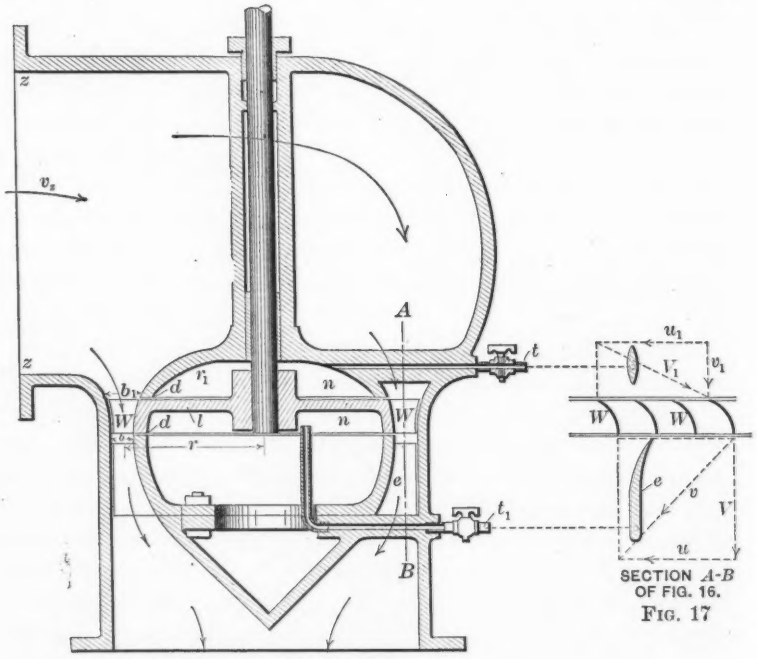
pumps. It may be said here that purely centrifugal pumps are not likely to be attempted in practice. (See page 510.)

Formulas Relating to Impulse Pumps.—Consider first the general case of an outward-flow pump with guide vane, Fig. 15 (*b*). Then, using the symbols heretofore applied to centrifugal pumps, we have at the entrance

$$V_1^2 = v_1^2 + u_1^2 + 2\, u_1\, v_1 \cos.\, \phi \ldots\ldots\ldots\ldots\ldots\ldots (X)$$

Equation *I* applies to this case. Hence

$$V^2 = V_1^2 + u^2 - u_1^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (I)$$



PARALLEL-FLOW IMPULSE PUMP.

FIG. 16

SECTION *A-B* OF FIG. 16.

FIG. 17

and at the discharge we have, as in centrifugal pumps,

$$v^2 = V^2 + u^2 + 2\, u\, V \cos.\, \beta \ldots\ldots\ldots\ldots\ldots\ldots\ldots (II)$$

These formulas are general, from a theoretic point of view. They show that to get the greatest lift, $\frac{v^2}{2\,g}$, with a fixed u and v_1, the angles, ϕ and β, should be as small as possible; but, from a more practical point of view, there are sharp limitations to this. Notice that the

length of the vanes is not involved in the foregoing formulas. Remember, also, that to reduce friction losses, the surface over which the water passes at a high velocity should be the least possible, consistent with other requirements. For this reason it will probably be found best to make the vanes short, even at the sacrifice of some of the curvature. Furthermore, the construction will be simplified and cheapened by omitting the guide vanes, g, g. Then ϕ becomes 90 degrees. For similar reasons, β will usually be 90 degrees. Under these conditions, substituting from Equations X and I, since cos. ϕ and cos. β are both zero, Equation II becomes

$$v^2 = 2\,u^2 + v_1^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (XI)$$

The same reasoning and the same formulas will apply where the flow is parallel to the axis, as in Fig. 16. In this case, $u_1 = u$, and therefore $V_1 = V$. This is also evident on inspection.

By the law of hydraulics, that velocity head plus pressure head = total head:

$$p + \frac{v_1^2}{2\,g} = k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (XII)$$

Notice that p reaches the entrance vanes, for there is no change of pressure; and, since the head, H, must be imparted to the water while it passes between the vanes, we have, by the law of conservation of energy, neglecting the velocity in the discharge main,

$$k + H = \frac{v^2}{2\,g} + p = h;$$

then, taking the equivalent of $k - p$ from Equation XII,

$$H = \frac{v^2}{2\,g} - (k - p) = \frac{v^2 - v_1^2}{2\,g} \ldots\ldots\ldots\ldots\ldots (XIII)$$

In this case k can never equal p, for, if it did, v_1 would be zero, and no work would be done.

Remember that when p and k represent suction they are in themselves minus, independently of the signs of the equation.

If in Equation XIII, which is general, we substitute the special value of v^2 from Equation XI we get

$$v^2 = g\,H \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (XIV)$$

Notice that Equations XI and XIII should not be applied except under the conditions specified in deriving Equation XI. These conditions, however, will be common ones in practice.

Suction Head in Air-Chamber.—On page 504 it is stated that the pressure should not change while the water is passing out between

the vanes. The pressure which actually exists is p; that fixed by the suction in the throat, m. (The remarks on page 498 apply in this case as well as in centrifugal pumps.) In this case the pressure, p, reaches the entrance to the vanes, and, by Equation *XII*, v_1 depends on p; k being assumed as fixed. Theoretically, $p = h - \frac{v^2}{2g}$ (neglecting friction and velocity in the discharge pipe). If, in this case, we substitute the value of v^2 from Equation *XI*, and then the value of v^2_1 from Equation *XIII*, we get

$$u^2 = g\,(h + k - 2p) \ldots\ldots\ldots\ldots\ldots\ldots (XV)$$

If Equations *XIV* and *XV* are found to be inconsistent, the former should have precedence. Notice that p does not affect the lift, H, but does affect the discharge by its influence on v_1.

It appears, then, that until we have some experimental data concerning p, the discharge of such pumps cannot be predicted accurately. Equations *VI*, *VII*, *VIII* and *IX* apply also to impulse pumps.

Areas of Passage Between Vanes.—Theoretically, we would get the same impulsive effect if the space between the vanes were only partly filled, as in Fig. 13 (*b*); but, to avoid all possibility of spraying, shocks, or sudden change of velocity, it is necessary that the water occupy the whole volume of the interior of the wheel, and issue therefrom in one unbroken sheet of uniform velocity around the circumference. In order that this condition be satisfied, and also that there be no change of pressure in the passage, it is necessary that the areas be proportioned carefully. Using the same symbols, and assuming that there are guide vanes at the entrance, in Fig. 14 (b), we have, since $v_1 \sin. \phi$ is the radial component of the velocity at the entrance,

$$v_1 \sin. \phi \times 2\,\pi\, r_1\, b_1 = Q \ldots\ldots\ldots\ldots\ldots\ldots (IX)$$

Whence we get b_1. Similarly, at the exit we have for the radial component: $V \sin. \beta$, or $v \sin. \theta$.

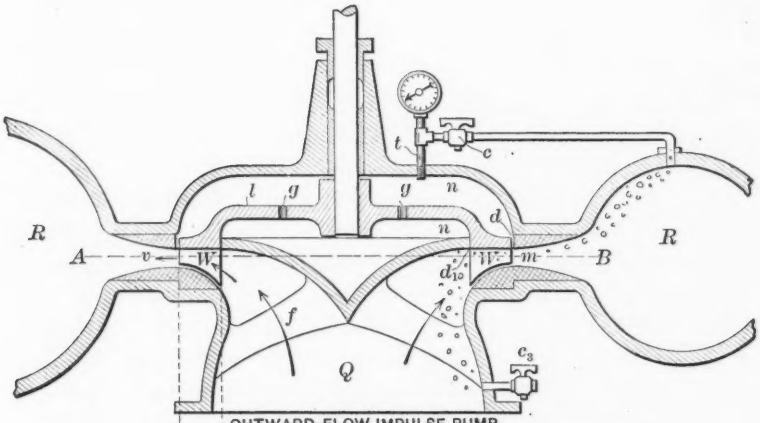
Hence,

$$V \sin. \beta \times 2\,\pi\, r\, b = Q \ldots\ldots\ldots\ldots\ldots\ldots (VIII)$$

Whence we get b.

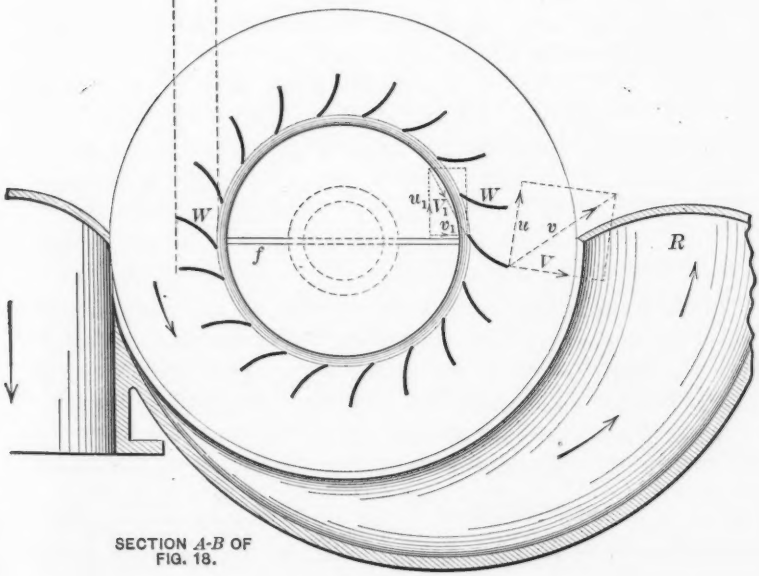
Evidently, in these, we assume that the vanes begin and end in a knife-edge. At any intermediate section of the passage the thickness of the vanes must be considered. The relative velocity at any intermediate section can be found by Equation *I*, viz.,

$$V^2_a = V^2_1 + w^2_a - u^2_1,$$



OUTWARD-FLOW IMPULSE PUMP.

FIG. 18.



SECTION *A-B* OF FIG. 18.

FIG. 19.

and the radial component is always

$$R_a = V_a \sin. \beta_a;$$

and

$$R_a (2 \pi r_a - n t) b_a = Q.$$

Whence b_a.

The subscript, a, indicates the intermediate section; n = number of vanes in the pump, and t = thickness of the vane at the point, a. This refinement need never be applied in practice.

There is no apparent mechanical principle, or practical difficulty, that would prevent the combination of centrifugal and impulsive effects. In that case the areas of the passageway need not be proportioned as carefully; but, on the other hand, since the pressures at the entrance and the discharge to the vanes would no longer necessarily be equal, the wheel, disk, or web, should be made solid, and air admitted to the opposite sides by separate tubes, as at t and t_1, in Fig. 16; otherwise the web of the wheel can be perforated as at q, in Fig. 18, and the pipe, t_1, omitted.

Proportioning.—For convenience, the necessary general formulas for designing impulse pumps are here reprinted:

$$V^2_1 = v^2_1 + u^2_1 + 2 v_1 u_1 \cos. \phi \ldots\ldots\ldots\ldots (X)$$

$$V^2 = V^2_1 + u^2 - u^2_1 \ldots\ldots\ldots\ldots\ldots\ldots (I)$$

$$v^2 = V^2 + u^2 + 2 u V \cos. \beta \ldots\ldots\ldots\ldots (II)$$

$$H = \frac{v^2 - v^2_1}{2 g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (XIII)$$

$$Q = 2 \pi r_1 b_1 v_1 \sin. \phi \ldots\ldots\ldots\ldots\ldots\ldots (IX)$$

$$Q = 2 \pi r b V \sin. \beta \ldots\ldots\ldots\ldots\ldots\ldots (VIII)$$

In parallel-flow pumps, r_1 must be taken as the radius to the center line of the inlet, and r that to the center line of the outlet to the vanes, and b_1 and b are the widths of the vanes, radially, at the inlet and outlet, respectively. See Fig. 16.

When ϕ and β are both 90 degrees:

$$v^2 = 2 u^2 + v^2_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (XI)$$

$$u^2 = g H = \frac{v^2 - v^2_1}{2} \ldots\ldots\ldots\ldots\ldots\ldots (XIV)$$

$$Q = 2 \pi r_1 b_1 v_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (IXa)$$

$$Q = 2 \pi r b V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (VIIIa)$$

The order of proceeding, to get the chief dimensions of an outward-flow impulse pump, would be about as follows: Q and H being

given, k will be determined by considerations of convenience. The diameter of the entrance to the wheel will be fixed by the permissible velocity at the entrance, which may be 10 ft. or less; say v_z. Then $\pi r^2_z v_z = Q$, if the inlet is on one side only, or $2 \pi r_z v_z = Q$, if on both sides. Thence, r_z. Then r_1 of the equations for the outward-flow pump should be a little greater than r_z, in order to provide a short curved approach to the vanes.

Next, we must decide on v_1. This depends on p, which is a matter of some uncertainty until some experimental data are collected. See page 508. For the present discussion v_1 will be assumed as determined. Then b_1 is obtained from Equations *IX* or *IXa*.

The outer radius, r, may be fixed by considerations of convenience of construction, and whatever light experience throws on the subject. Undoubtedly, the vanes should be as short as possible, consistent with other necessary conditions. When a length of vane is thus fixed the next step should be to find a corresponding value of u that will give the necessary head. Unfortunately, the direct determination of u from Equations *X*, *I*, *II* and *XIII*, when H, v, β, and ϕ are given, is a difficult problem. For a single computation it would be easier to assume values of u and compute H, until, by trial, a sufficiently close value of u is found. If much work of this kind has to be done, tables should be prepared showing the relations between u and H for such values of β and ϕ as may be put in common use.

When u is determined, V can be obtained from Equations *X* and *I*, and then b can be found from Equation *VIII*.

Should it be determined to make the pump without guides, and to make $\beta = 90°$, then special Equations *XI*, *XIV*, *IXa* and *VIIIa* enable us to proceed directly.

The fixed vanes, e, are to stop the revolution of the water and direct it along the discharge pipe. Three such vanes should suffice.

The reaction, R, parallel to the axis, due to the discharge of the water from the wheel, will be, from the well-known laws of reaction:

$$\frac{WV}{g} \text{ or } \frac{10 \times 62.5 \times 58}{32} = 1\,130, \text{ nearly.}$$

In the method by which Equation *I* is obtained for impulse pumps and motors, the analysis follows a single particle. This, of course, is not the actual condition, and the writer suspects that, in impulse pumps, and water-motors especially, the difference between the actual

and assumed conditions leads to serious errors. To explain: Suppose the vane, $d\,e\,f$, Fig. 20, to move with the velocity, u; our analysis assumes only one thin lamina of particles following the surface of the vane, but, in practice, there would be a considerable depth normal to the vane, and each lamina is deflected by pressure (or reaction) from the next one beneath. Thus the lamina against the vane must be under greater pressure than the outer one, and where the water reaches the discharge line, $d\,a$, that at d will escape with greater velocity than that at a.

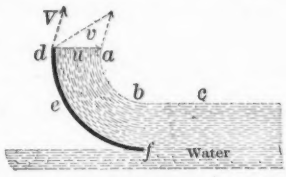


FIG. 20.

It appears that the above circumstance will make our formulas for impulse pumps unreliable, and it must also reduce the efficiency seriously, for there must be considerable loss by friction when the laminæ of water move with high and low velocities side by side.

The best remedy the writer can suggest is to increase the number of vanes, to divide the water into thin laminæ, until the advantage thus gained is lost by increase of surface friction. Further discussion on this point will be found on page 517.

The foregoing discussion will not apply to centrifugal pumps, properly so called, for there the area of passage should be so large that, by thus reducing the velocity, all the liquid is brought to one condition as to pressure and velocity before escaping. See page 494.

Fig. 21 shows diagrammatically what Mr. J. Richards calls an impulse pump. The writer is unable to see in it any advantage justifying its existence, but rather the contrary. One extraordinary condition in this design is that the flow between the propellers is not continuous. A glance at the figure will show that the discharge, during the instant in which any two propellers occupy the positions, $a\,e$ and

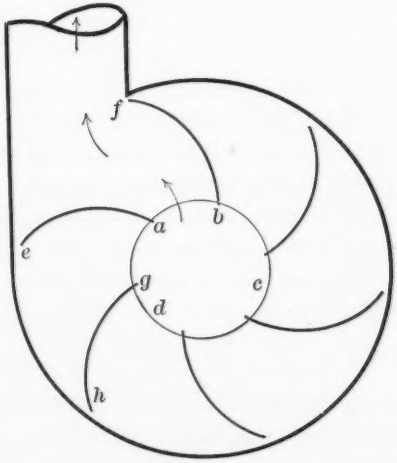


FIG. 21.

bf, is limited to the channel, ab–ef, and the velocity through ab must be high. The next instant, when e passes f, the outward motion of the water in $eabf$ must be stopped, and, in the same time, that in $hgae$ must be given the outward motion. It is, indeed, a thing of impulses. Surely such conditions are not favorable to smooth working and high efficiency.

Empirical Coefficients.—In all that has preceded, perfect efficiencies have been assumed, in order to present the underlying principle clearly. Every reader knows that results computed by the various formulas cannot be realized in full. Experience alone can supply the coefficients necessary to make them sufficiently correct for practice. Until some experiments are available the following may give some light on this matter:

After a wheel is built, as the lift depends only on the peripheral velocity, u, by computing u for a head greater than that specified, allowance can be made for imperfect efficiency. For instance, if the efficiency in lift is known to be 75%, and u is computed for $\frac{4}{3}H$, we will get the head required.

In the matter of discharge, it is known that the coefficient of discharge from well-rounded nozzles is very nearly unity. Hence, it is probable that the equation for fixing the dimensions of the passage will give results which are nearly correct when the approaches are rounded properly.

Practical Limitations.—A little inspection of the equations, and the solution of a few numerical examples, will reveal the unfortunate fact that these pumps, either centrifugal or impulse, in which the pressure in the air-chamber is below that of the atmosphere, are not applicable when the quantity of water to be pumped is small, while the head is high; the reason being that the width of the peripheral discharge slot becomes impracticably small. Just where this limit will be drawn in practice the writer will not undertake to say. See page 514.

Example.—Proportion a pump to lift 20 cu. ft. per second through 10 ft.

Let the entering velocity to the wheel, $v_x = 15$ ft., and to the vanes, $v_1 = 10$ ft.; then the area of the circular entrance must be 1.33 sq. ft., or the diameter nearly 15½ ins.

Now, if we make $r_1 = 9$ ins., it will give 1¼ ins. for curving the approach to the vanes. Then, by Equation *IX*, b_1 is found to be

nearly 5 ins. If ten vanes are put in they will be nearly $5\frac{1}{2}$ ins. apart at the entrance. If they are made 4 ins. deep, radially, r becomes 13 ins. Then, by Equation *VIIa*, it is found that $u^2 = 320$, or u should be about 18 ft. per second, or about 2.6 revolutions per second. From Equation *VI* (assuming $k = p$), $V = 18$, nearly, and from Equation *VIIIa*, $b = 0.2$ ft., or nearly $2\frac{1}{2}$ ins.

Evidently, then, such a pump would pass any solid in which the greatest dimension does not exceed $2\frac{1}{2}$ ins. It may be worth while to notice that, should any solid, too large to pass, get into the pump, it will cause no break nor even a grinding on any surface, but will merely lodge in the wheel and turn with it.

It is stated, on page 503, that in proportioning pumps to work as there assumed, the width, b, of the annular discharge slot would sometimes be found impracticably small; and, for that reason alone, the scheme could not be applied in cases where the quantity required is small and the lift great, as compared with conditions under which centrifugal pumps usually work. This difficulty can be overcome by devices now to be described.

The chief purpose now in view is to surround the propelling wheel with air at a pressure above that of the atmosphere, so that the necessary conditions,

$$\frac{v^2}{2g} + p = h,$$

may be fulfilled when $\frac{v^2}{2g}$ is less than h. Or, in other words, so that the velocity of discharge, v, can be reduced and the discharge area, $2\pi r b \sin. \beta$, be increased accordingly.

For accomplishing this purpose, Fig. 22 shows a scheme which has some additional points of advantage. In this, the air in the chamber, n, is not taken directly from the atmosphere, as in the previous propositions, Fig. 11. It is first taken into the intake or suction pipe, Q, through a cock c_1 (or, if the water is naturally gaseous, c_3 may be closed or omitted). The air then passes through the pump as entangled bubbles, and is drawn out of the discharge pipe wherever most convenient, and permitted to enter the chamber, n, through the pipe, S, the rate of passage being controlled by a cock, c_2.

That the above described action can be obtained will be apparent from the following:

The pressure of the air in the discharge pipe will be that due to the

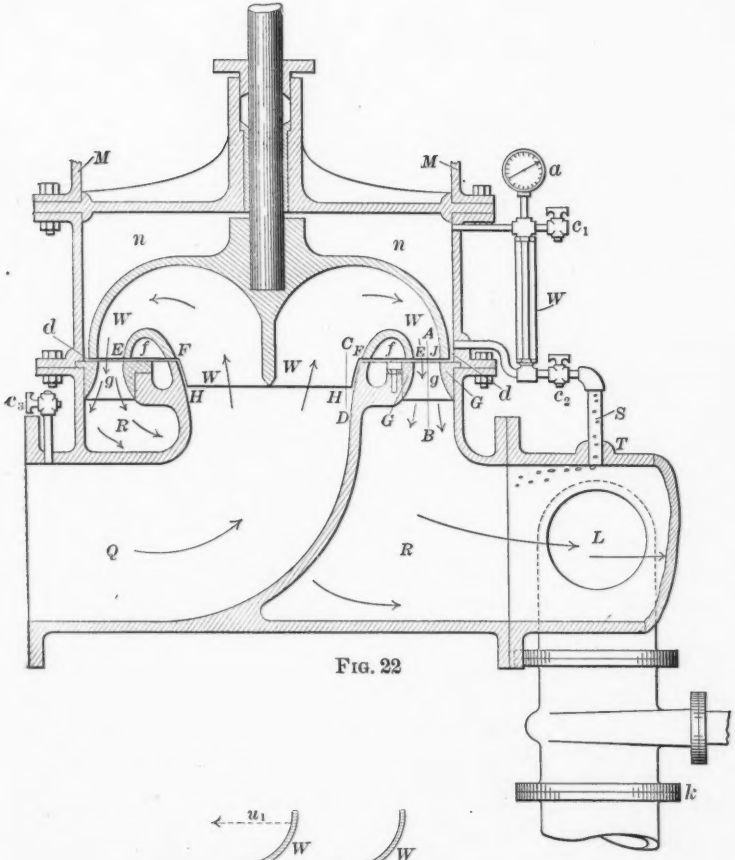
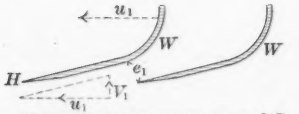
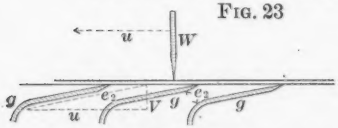


FIG. 22



DEVELOPMENT OF INTAKE VANES, ON *C-D*.

FIG. 23



DEVELOPMENT OF FIXED VANES, *g*, ON *A-B*.

FIG. 24

remaining lift, h, while that in the chamber, n, must be the same as the pressure in the water as it passes the open joint, d. Now, by well-known laws of hydraulics, the pressure at the joint, d, where the velocity is high ($v^2 = V^2 + u^2 + 2\ u\ V \cos.\ \beta$), cannot be as great as that in the discharge pipe where the velocity is low (the slight difference of elevation being neglected). Hence there will be a tendency for the fluid to flow through the pipe, S, and the cock, c_2, into n. The pipe, S, of course, should tap the discharge pipe at a point where the air tends to collect. A very small stream of air entering c_3 will suffice, for all that is necessary is to replace the leakage of air through the stuffing-box. The circulation can be controlled by adjusting the cocks, c_3 and c_2. Any surplus of air will pass off through the discharge pipe. The water gauge, W, will show whether or not the chamber, n, is free of water. The pressure gauge, a, is not essential, but should always be attached, as it gives valuable information.

The advantage of this scheme, as announced at the outset, is that the width, b, or $E\ J$ of Fig. 22, is not restricted; but, where high efficiency is the object, the fixed deflecting vanes, $g\ g$ (Fig. 24), should be inserted to turn the water downward, thus stopping its revolution and checking its velocity accordingly, as soon as it leaves the propeller (more fully explained later). This will prevent what might be serious loss due to fluid friction.

In this design the propeller vanes, $W\ W$, extend to the center (though this is not essential). By this means, it is believed, the water will be taken up with less shock, and can be brought to a state of steady rotation before discharge, with more certainty and with fewer propelling vanes. With this intention, the designer should see that the vane everywhere parts the approaching water without conflict. To meet this condition the vanes should be vertical at the center and have a gradually increasing forward pitch at the lower edge as the distance from the center increases.

Notice that there is no tendency for the water to flow back through the joint, $E\ F$, for the water at F is already under centrifugal force, and hence there is as much tendency for the water to flow out through $F\ E$ as to flow back.

The design, Fig. 22, is the writer's study, to combine, in the highest degree, compactness, simplicity of castings, and efficiency. Some other designs embodying the chief features are shown in Figs. 30 and 32.

When this style of pump is to be applied in dredging, the deflecting vanes, $g\ g$, should be omitted, the propelling vanes, W, made few and strong, and the receiving chamber, R, be made a "volute," that is, the area of R should increase progressively in the direction of revolution, and the water in it should move in the direction of revolution only. Thus modified, there is no apparent reason why it should not give excellent results as a dredge pump. Note that grit cannot get to the bearings, and that the area of discharge is unrestricted.

Concerning the pressure, p, in the chamber, n, the following may be interesting:

A necessary relation is $\frac{v^2}{2g} + p = h$.

Doubtless, such pumps will usually be made with the outer tips of the propelling vanes perpendicular to the direction of motion ($\beta = 90°$); then $v^2 = V^2 + u^2$. Substituting, we get

$$\frac{V^2}{2g} + \frac{u^2}{2g} + p = h.$$

Now, the object of this design is to make V small, and it should be less than 8 ft. On this assumption, $\frac{V^2}{2g}$ will be less than one. Hence, for the present purpose, it may be neglected. Remember, also, that $\frac{u^2}{g} = H$. (See pages 487 and 488. Substituting this, the relation becomes $p = h - \frac{H}{2}$, approximately.

Theoretically, the equations derived heretofore will apply to this design; but, practically, they are of little value (except the relation, $u^2 = g\,H$), for in this case a convenient value for V (4 to 8 ft. per second) can be assumed, and the parts proportioned consistently.

That the assumed V may be realized, the actual effective lift must be something less than the maximum theoretic lift, H, reduced by whatever friction losses occur beyond the open joint, d. This is a matter that cannot be formulated. Experience alone can give light upon it.

Relation of Vanes to Each Other.—In the preceding discussions it has been pointed out repeatedly that the edges of the vanes should be set so that the passing water will be parted without shock or "eddies," that is, they should be in the plane of relative motion. We have now to consider the best relation of one vane to the next.

It has also been pointed out that the common forms of centrifugal pumps lose, by "drag" at the tips of the propellers, most of the energy due to velocity ("kinetic" energy), and that this is just half of the energy in the water. It is therefore well to give some study to a means of better utilizing this kinetic energy.

The writer proposes that the vanes should be so related as to form flaring nozzles, of the best possible form consistent with other essential conditions of construction, and this should be done both in the starting or intake vanes and in the fixed deflecting vanes at the discharge.

In support of this opinion, attention may be called to the fact, well established by experimental hydraulics, that the efficiency of a properly proportioned discharge nozzle (water flowing toward the contraction) is about 98%, and, while recorded experiments on receiving nozzles (water flowing away from contraction) are not as numerous or varied, it is rational to presume that the action can be reversed, in correctly designed nozzles, without serious loss.*

Figs. 23 and 24 show vanes designed to act as receiving nozzles to go in the pump shown in Fig. 22. Note that the inclination of the vanes on the side from which the water approaches is such that the motion of the water is not affected until it enters the nozzle, *e*. For instance, in Fig. 23, which shows the conditions at the entrance, the water has only a low vertical velocity, which continues undisturbed as it rises under the helicoidal surface of the vane until it is struck and taken in by the orifice, *e*; then, being in the revolving nozzle, that is, between the vanes, it must take the revolving motion quickly. Here, the nozzle moves against nearly still water, while, at the discharge, Fig. 24, the water moves against fixed nozzles. The relative action is similar in the two cases.

* On this subject, the writer was somewhat discouraged and puzzled by that portion of the "Lowell Hydraulic Experiments" relating to discharge through a flaring ajutage (nozzle), in which it is pointed out that fifteen-sixteenths of the energy of discharging water was lost in the tube, but there is nothing irrational or discouraging about it when we are reminded that the absolute loss due to friction is independent of pressure. Hence if there had been 100 ft. of head on the nozzle, instead of 1 or 2 ft., with the same velocity, the percentage of loss would have been small. To satisfy himself on this question, the writer prepared the apparatus shown in Fig. 25 and tested the efficiency of the combination under various conditions.

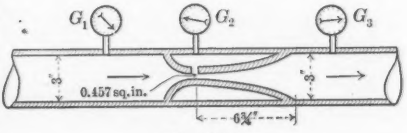


FIG. 25.

The records of two typical cases are as follows:

1.—Pressure head at $G_1 = 167$ ft.; at $G_2 = 0.0$; at $G_3 = 138$. Efficiency = 82.5%

2.— " " " $G_1 = 149$ " ; " $G_2 = -28$; " $G_3 = 117$. " = 78.5%

In the first the velocity at the throat was approximately 102, and in the second, 106 ft. per second. Doubtless, for less extreme cases, higher efficiencies can be obtained.

In this design the discharge will vary with the velocity (rate of revolution); then, knowing the peripheral velocity necessary to give the lift, the inclination of the vanes must be computed accordingly.

Example.—Proportion a pump, of the type shown in Fig. 22, with 14-in. intake, to lift 8 cu. ft. of water per second against a head of 48 ft.

First, to find the peripheral velocity, u: If an efficiency of 75% be assumed, the pump must be designed for a speed which would give 64 ft. lift, theoretically. Then, by Equation VII, $H = \frac{u^2}{g}$, $u = 45$ ft. per second (nearly), and this may be taken as the velocity of the center line of the discharge zone. Assume the diameter of this center line to be 24 ins. Then the revolutions per second will be 7.16. The velocity of the outer limits of the intake vanes, W, at H (where the radius = 7 ins.), will be $\frac{7}{12}$ of 45 = 26 (nearly), and, the vertical velocity of approach being 8 ft., the inclination of the vane at this point must be 8 vertical to 26 horizontal (4 to 13). The inclination becomes more nearly vertical as the center is approached, being vertical at the center.

Assuming the width of the discharge zone to be 4 ins., then the area is 1 sq. ft. (nearly), and, therefore, the vertical component of the velocity of discharge (or the velocity, relative to the revolving wheel) will again be 8 ft. (nearly). Hence, the fixed vanes at discharge must be inclined 8 vertical to 45 horizontal (1 to $5\frac{1}{2}$).

Some convenient formulas for proportioning pumps of the class shown in Fig. 22 are as follows:

Let S = slope, or tangent, of the inclination of fixed deflecting vanes, g;

" d = radial width of same = width of discharge zone;

" r = radius of center of discharge zone;

" u = velocity of rotation at radius, r;

" V = velocity of discharge relative to the revolving wheel = vertical component of absolute velocity of discharge;

" a = area of discharge zone = $2 \pi r d$.

Then $V = u S$, and $Q = a V = a u S$.

Similarly, let S_1, r_1, u_1 represent the slope, radius and rotative velocity, respectively, of the intake vanes at the outer limit; and let a_1 represent the area, and V_1 the velocity, in the intake.

Then $V_1 = u_1 S_1$; $u = \frac{r_1}{r} u$; $a = \pi r^2_1$; $Q = a_1 V_1 = a_1 u_1 S_1$.

Equating the two values of Q, we get

$$r a S = r_1 a_1 S_1.$$

Another equation easily proved is:

$$r^3_1 S_1 = 2 r^2 d S.$$

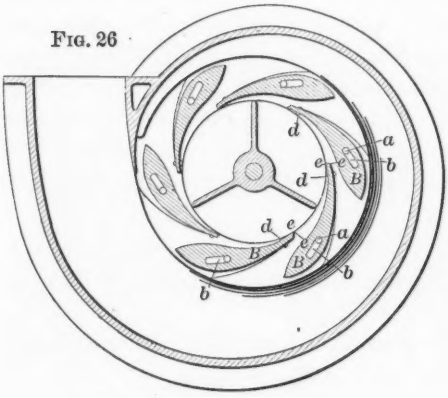
In such a pump, run at varying speeds, the discharge will vary directly with the speed, the lift with the square, and the work with the cube, of the speed. Evidently, then, such a pump cannot be adapted to varying conditions. This has probably been the greatest handicap to a more general use of centrifugal pumps; therefore, it is exceedingly desirable, in connection with other improvements, to make pumps of the best class adjustable.

Figs. 26, 27, 28 and 29 show the writer's design for an adjustable centrifugal pump. The discharge is dependent on the area of the orifices, *e e*, and this is controlled by swinging the vanes, *B*, about the hinges, *d*, thus affecting the opening, *e e*. From the adjusting ring, *A*, Figs. 27 and 28, the pins, *a*, *a*, etc., protrude through short slots, *c c* which are cut through the shell, *D*, on the circumference of a circle concentric with the wheel. These pins, *a*, engage the vanes, *B*, by entering the straight slots, *b*, cut in the vanes. When *A* is revolved, the pins, *a*, follow the slots, *c c*, and *B* must swing in or out accordingly. *A* is revolved through the necessary angle by the mechanism shown at *C*, Figs. 27 and 28, which may be duplicated on the opposite side. Fig. 26 shows the vanes, *B*, in place, with the upper plate removed. Fig. 28 shows the adjusting ring, *A*, lying in place. The inner curve of the vanes, *B*, is designed to maintain unchanged both the radial and revolving motion of the water; but, after it passes *e e*, into the flaring nozzle, the velocity is checked, and the pressure is increased accordingly.

The advantage of the down-and-out flow is in the opportunity it gives to support the weight of the wheel, shaft, etc., on high-pressure air from beneath, that is, in the chamber, *n*. In this case, where air occupies the space, *n*, below the wheel, the pressure is uniform, not being affected by the centrifugal force of the water revolving under the wheel, as assumed on page 496; hence, in this case, the uplift will be $\frac{62.5 \pi r^2 u^2}{2 g} = 3 r^2 u^2$ (nearly), in pounds, when r is taken in

feet. This is double the uplift obtained when water is revolving under the wheel—a point well worth notice in designing either pumps or water-wheels to operate on vertical shafts. Air can be conducted into this chamber by the means described on page 514, or by an inspirator, i, as shown in Fig. 27. The water for operating the inspirator can be drawn from any point in the discharge pipe. Note that the

FIG. 26



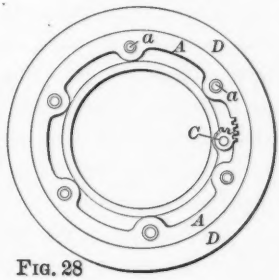
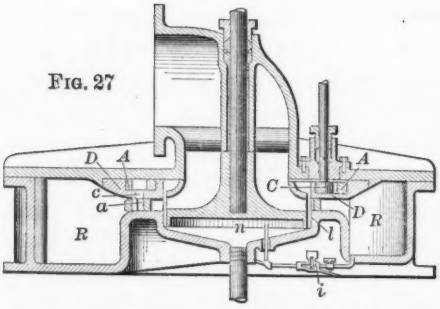


FIG. 28

FIG. 27



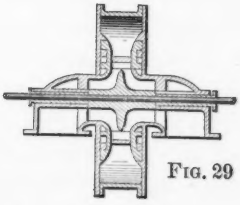


FIG. 29

pressure in n is that at the open joint, l, at the tips of the vanes, where the velocity is highest, and, therefore, the pressure in n will be less than in R (one-half, theoretically).

Fig. 29 shows the outlines of an adjustable, double-intake pump on a horizontal shaft; the adjustment to be made substantially as in the preceding. Such a design has very manifest advantages for a permanent plant to handle large quantities of water from a nearly permanent and easily accessible level.

It is noteworthy that the designs discussed on pages 520 to 521 have every element of a first-class "reaction" water-wheel (turbine), and, operated as such, will probably give good results.

Compounding.

The principle involved in compounding centrifugal pumps is simple enough. It consists in taking the water as delivered from one pump and passing it through another, thus getting the effect of each pump independently. But, when the designer takes up the problem, he finds an infinite variety of possible combinations, from which he must select that one which is most advantageous, everything considered, and he must consider, chiefly, compactness, simplicity of castings and efficiency of operation.

After studying the subject in the light of all that precedes in this paper, the writer offers the design for a compounding pump shown in Figs. 30 and 32.

Having explained all other new features in this design we have now only to explain the features involved in compounding.

The construction and operation, out to the lower edge of the fixed deflecting vanes, $g_1\ g_1$, is identical with that in the single pump, Fig. 22. At this point the water is flowing vertically and has a low velocity (all the motion of revolution having been checked by the vanes, g), and its pressure is that due to whatever head the single pump could produce. The water now comes in the path of a second set of propelling vanes, $W_2\ W_2$, which are attached to the same revolving piece that carried the first set, $W_1\ W_1$, as is shown plainly in Fig. 30. This second set of vanes must be set so that the upper edge will part the water without shock—which is a matter of simple geometry. The water, in gliding between the vanes, W_2, partakes of their velocity, and, hence, at the line of escape, or lower edge of W_2, the water again has a high velocity, as shown by the dotted lines in Fig. 31, but, immediately after its escape from W_2, the water comes against a second set of fixed deflecting vanes, g_2, by which the component, u, of its velocity is again checked and the pressure increased correspondingly, according to the well-known law of hydraulics.

Thus, the pressure can be increased indefinitely by a succession of moving and fixed vanes.

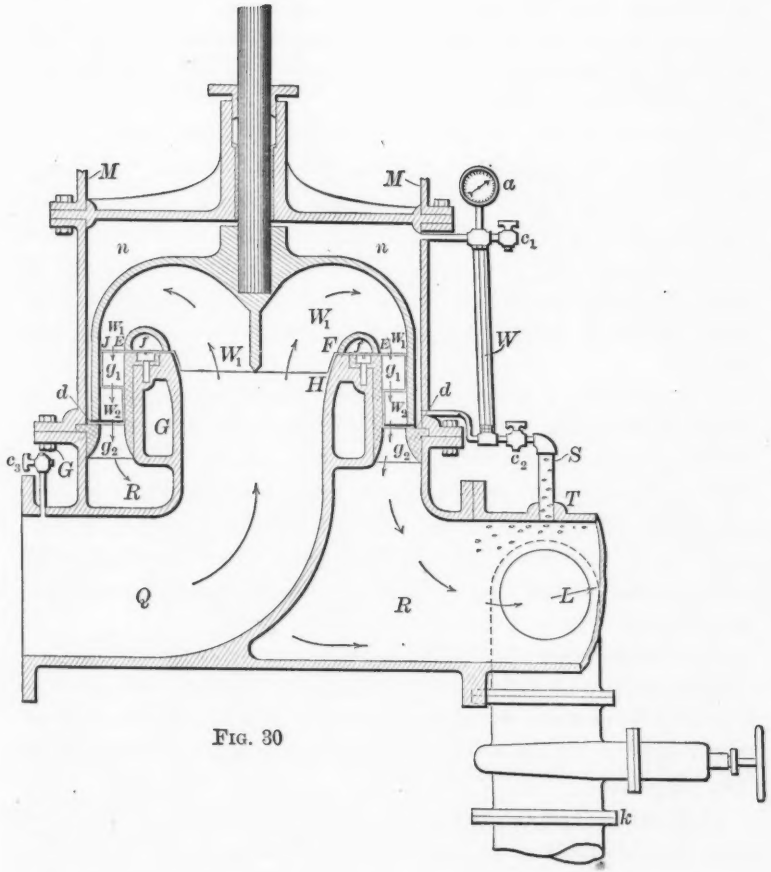

M
M
a
c_1
n
n
W_1
W_1
W
F
H
d
d
G
G
R
c_2
S
T
Q
R
L
k

FIG. 30

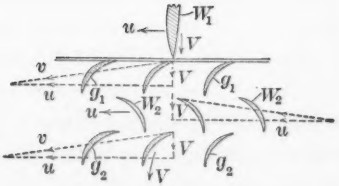

u
W_1
V
v
u
g_1
V
g_1
W_2
u
W_2
V
u
v
u
g_2
V
g_2

FIG. 31

It can be shown (see page 507) that the effect of the vanes, W_2, will be exactly equal to that of the first set of vanes, W_1, which act more nearly under the laws of purely centrifugal force.

The details of construction can be varied indefinitely, but the simplicity of that shown in Fig. 30 is not likely to be surpassed unless it be by that shown in Fig. 32.

Note that in Fig. 30 the area of the horizontal section of the water channel is constant between the first and last lines of discharge. Hence the vertical component, V, of the velocity must be constant. This simplifies very much the construction and also the problems in proportioning. The flow, of course, could be made radial and yet retain the novel feature here described, but the space occupied by the pump would be increased very much and the construction complicated.

Fig. 32 shows a compound turbine* pump, which will now be readily understood. The water enters from above, through Q. The space, n_2, will be occupied by air below atmospheric pressure (if Q is under suction), the air being admitted through a cock on the pipe, t_1; the air thus admitted doing, also, the duty of that admitted through c_3 of Fig. 30. The space, n_1, will be occupied by air at high pressure admitted through the pipe, S, by the process described in connection with Fig. 22.

This design has one additional and noteworthy advantage, in that the high pressure is under the wheel, and all the reaction of the flowing water is upward. Thus the weight of the wheel and a shaft of length equal to the lift can usually be fully supported, and often more than supported.

As an example of the theoretic porportions of pumps of the style shown in Figs. 22, 30 and 32, the following is offered:

Assume an intake pipe, 8 ins. in diameter, and an intake velocity of 8 ft. per second. This gives 2.8 cu. ft. per second. Assume the outer diameter of the discharge (to J) = 13 ins., and the inner diameter (to E) = 10 ins., or $b = 1\frac{1}{2}$ ins. Then the discharge area = 0.376 sq. ft., and the vertical component of the velocity there = 7.4 ft. per second, and this does not change until the horizontal area changes.

Assume 800 revolutions per minute. Then the velocity, u, of the outer tips of the vanes will be nearly 42 ft. per second, and the theo-

* This non-committal name is used because the action is neither purely centrifugal nor impulsive.

retic lift, $H = \frac{u^2}{g}$, will be nearly 50 ft. when the outer tips of the propelling vanes are perpendicular to their motion, that is $\beta = 90$ degrees.

Under the above conditions, the inner tips of the vanes, where they take up the water at H, should slope $4\frac{1}{2}$ horizontal to 1 vertical, as at

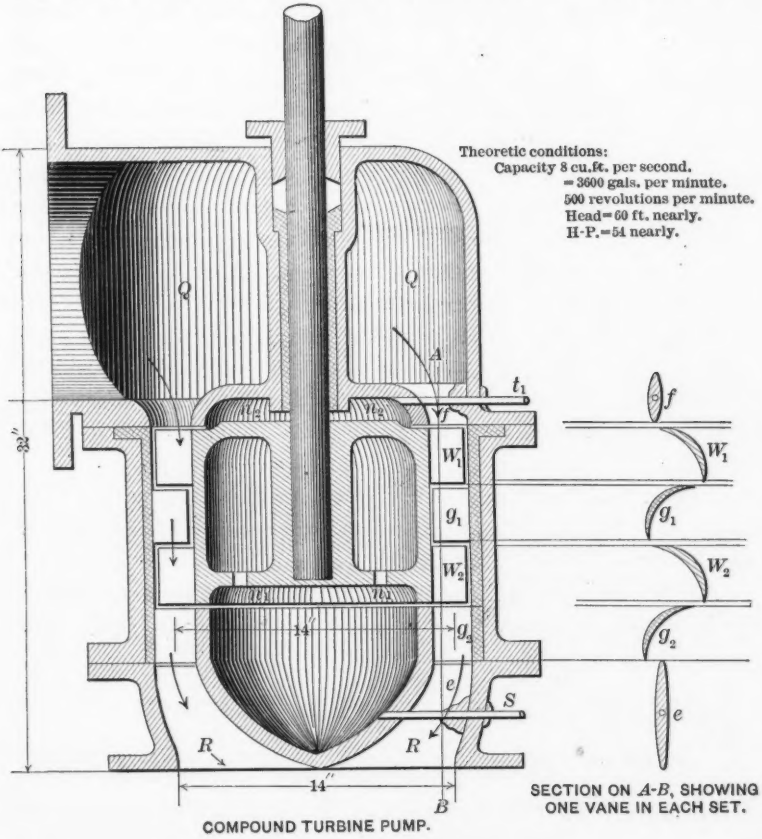


FIG. 32.

b, Fig. 27, and the top edge of the fixed deflectors, g, should slope in the opposite direction about 6 to 1, as at a, Fig. 30.

The extreme outside diameter (over the flange) of such a pump would be about 21 ins. The figures are drawn to scale and show the proportionate heights.

The lift found for a single-acting pump can be doubled (theoretically) by compounding, as in Figs. 30 and 32, which are drawn to scale and show how little additional weight or work would be necessary to accomplish that result.

Fans.

The demonstrations and formulas heretofore given, relating to both centrifugal and impulse pumps, apply to any fluid of constant density. Notice that weight, or density, appears in none of the formulas for dimensions, velocities or heads. If, then, we enter the study of fans or blowers, assuming that the change of density of the air (or any gas) while passing through the machine is so slight that it may be neglected, we can accept without question any of the formulas offered for either centrifugal or impulse pumps. Indeed, it has already been stated that in impulse pumps there should be no change of pressure in the fluid as it passes through the vanes. Then the formulas for impulse pumps apply to fans, without any qualifications.

It will be shown presently that the simplest, cheapest and probably the most efficient fan will discharge under atmospheric pressure. It will now be shown that in that case, also, the equations will stand, although centrifugal force may cause a compression within the wheel.

In Fig. 1 assume the cylinder, CB, filled with a compressible fluid, as air, then the weight of a unit volume will not be constant, but will depend on the distance, x, from the center.

Let W' represent this weight at the distance, x, from the center. Then the centrifugal force, due to a disk of unit area and infinitesimal thickness, dx, will be

$$df = \frac{W' u^2}{g x} dx = \frac{W' u^2}{g r^2} x\, dx, \text{ since } u_x = \frac{x}{r} u.$$

Also,

$$\frac{W'}{W} = \frac{f}{p_a}, \text{ where } f = \text{the absolute pressure in the fluid at the distance, } x, \text{ from the center, and } W \text{ and } p_a \text{ are the weight and pressure, respectively, of free air.}$$

Substituting and dividing by f we get

$$\frac{df}{f} = \frac{W u^2}{g r^2 p_a} x\, dx.$$

Then

$$\int_{p_a}^{p_1} \frac{df}{f} = \frac{W u^2}{g r^2 p_a} \int x\, dx.$$

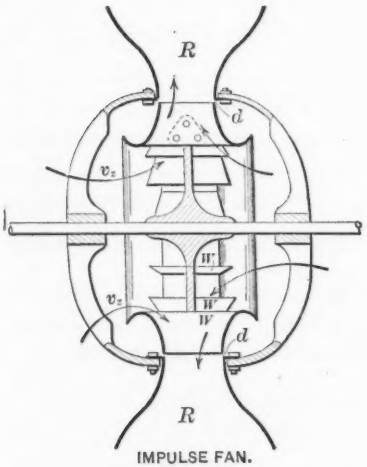
Whence,

$$\log. \frac{p_1}{p_a} = \frac{W u^2}{2 g p_a r^2} (r^2 - r^2_1)$$

Whence p_1 is the pressure at the outer limit, B.

Now, assuming no change of temperature, it is known that whatever energy is pent up in the compressed gas within the wheel must be as kinetic energy (energy of motion), when the gas escapes under atmospheric pressure. The energy in the gas within the wheel is partly in the pressure and partly in the velocity of revolution. Hence we have the equation

$$p_a Q_a \log_e. \frac{p_1}{p_a} + \frac{W Q_a u^2}{2 g} = \frac{W Q_a v^2}{2 g};$$



IMPULSE FAN.
FIG. 33.

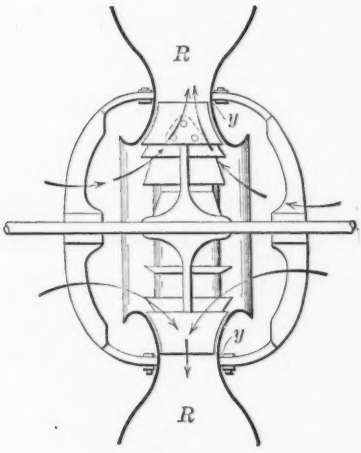


FIG. 34.

where v is the absolute velocity immediately after escaping. Substituting the value of $\log. \frac{p_1}{p_a}$, found above, the equation reduces to $v^2 = 2 u^2 - u^2_1$, which expression will be obtained by the analysis on page 482 when the velocity of approach is omitted.

In the writer's opinion, fans should be designed and proportioned in accordance with the principle of impulse pumps, except that the enclosing casing can be omitted. See Fig. 33. Such constructions have the following advantages:

(*a*)—They are composed of few and simple parts.

(*b*)—The vanes being short, radially, great inlet area can be pro-

vided in a fan of comparatively small diameter, and the discharge increased correspondingly.

(*c*)—The condition that the discharge is at atmospheric pressure renders the mathematical analysis of the action simple, and satisfactory formulas for proportioning and speeding a fan can be obtained.

(*d*)—The condition as to pressure (or suction) at the joint, *d*, reveals whether or not the wheel is speeded and proportioned properly.

Furthermore, these impulse fans (if that name be accepted) will, for reasons of simplicity and economy, probably be without guide vanes, and, for similar reasons, the moving vanes may be assumed to be radial at the outer end. It is apparent, further, that since the air enters and leaves at atmospheric pressure, the two factors, k and p, in the equations, disappear or balance each other. Thus simplified, the principle formulas become:

$$v^2 = V^2 + u^2 = 2\,u^2 + v^2_1 \ldots\ldots\ldots\ldots \quad (XI)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \ldots\ldots\ldots\ldots\ldots\ldots \quad (IXa)$$

$$Q = 2\,\pi\,r\,b\,V \ldots\ldots\ldots\ldots\ldots\ldots (VIIIa)$$

As the air passes by the joint, *d*, its energy is all kinetic, or $E = \frac{W\,Q\,v^2}{2\,g}$, but after it gets into the discharge conduit its energy will usually be partly due to pressure and partly due to velocity. Thus, suppose there is required an absolute pressure, p_2, and a velocity, v_2, in the conduit; then, by the law of conservation of energy,

$$E = \frac{W_a\,Q_a\,v^2}{2\,g} = p_a\,Q_a\,\log_e \frac{p_2}{p_a} + \frac{W_a\,Q_a\,v^2_2}{2\,g}.$$

Whence,

$$v^2 = \frac{2\,g}{W}\,p_a \log_e R + v^2_2 \ldots\ldots\ldots\ldots\ldots (XVI)$$

Where log. R = hyperbolic log. of $\frac{p^2}{p_a}$, W = weight of air = 0.076 lb. when the temperature is 60° Fahr., and $p_a = 2\,116$ lbs. per square foot. Inserting the numerical values, we get

$$v^2 = 1\,782\,000 \log.\ R + v^2_2 \ldots\ldots\ldots\ldots\ldots (XVIa)$$

While Equation *XVIa* is theoretically correct, it is the common practice to neglect the effects of compression, and work by equations identical in form with those used in hydraulics, differing only in the weight of the fluid and in the coefficient of friction. This practice is sufficiently accurate for practical purposes, within the ordinary limits

of compression produced by fans. Thus, instead of the equation above for E, the equation for energy would be written

$$E = P\,Q_1 + \frac{W\,Q_a\,v^2_2}{2\,g} = \frac{W\,Q_a\,v^2}{2\,g};$$

where P is the pressure above the atmosphere, and Q_1 is the volume at the pressure, P; but, if compression is neglected, Q_1 may be taken $= Q_a$; then Equation *XVIa* reduces to

$$v^2 = \frac{2\,g\,P}{W} + v^2_2 \ldots\ldots\ldots\ldots\ldots\ldots (XVII)$$

or, inserting numerical values, this becomes

$$v^2 = 842\,P + v^2_2 \ldots\ldots\ldots\ldots\ldots\ldots (XVIIa)$$

Results computed from Equations *XVIa* and *XVIIa* will not differ enough to affect the dimensions in designing. Hence, the latter, being much simpler, is preferable for that purpose; but, in computing the efficiency of a fan, Equation *XVI* should be applied, and a value of W inserted, according to the temperature of the passing air.

Example.—Proportion a fan to deliver 400 cu. ft. per second of free air (at a temperature of 60° Fahr.) into a passage where the pressure is 2 ins. of water (10.4 lbs. per square foot), the velocity to be 16 ft. per second ($= v_2$). See Fig. 33.

$$R = \frac{2\,116.8 + 10.4}{2\,116.8} = 1.005;$$

$$\text{Log.}_e\,R = 0.005;$$

and $$v^2_2 = 256.$$

Then, by Equation *XVIa*,

$$v^2 = 1\,782\,000 \times 0.005 + 256 = 9\,166, \text{ or } v = 96, \text{ nearly.}$$

By Equation *XVIIa*,

$$v^2 = 842 \times 10.4 + 256 = 9\,012, \text{ or } v = 95, \text{ nearly.}$$

Evidently, either result will be sufficiently accurate for designing.

Now, if an entrance velocity, v_2, of about 60 ft. per second is allowed, the area of the entrance $= \frac{400}{60} = 6.66$ sq. ft., or 3.33 sq. ft. on each side. The area of a circle of 1 ft. radius is 3.14 sq. ft. Hence we may take $r_1 = 1$ ft., making $v_2 = 63$.

Assuming the velocity at the entrance to the vanes, v_1, to be the same as v_2, we have,

$$Q = 400 = 2\,\pi\,r_1\,b_1\,v_1,$$

whence

$$b_1 = 1 \text{ ft., very nearly.}$$

Now, if there are twelve vanes, they will be about 6 ins. apart at the inner tip. Then a radial length of 6 ins. for the vane seems to be sufficient. This will make the fan wheel 3 ft. in diameter.

By Equation *XI*,

$$u^2 = \frac{v^2 - v_1^2}{2} = \frac{1}{2}(9\,012 - 3\,960) = 2\,512, \text{ and } u = 50, \text{ nearly.}$$

Also, by Equation *III*,

$$V^2 = v^2 - u^2 = 9\,012 - 5\,043 = 3\,969, \text{ and } V = 63.$$

Then, by Equation *VIIIa*,

$$400 = 6.28 \times 1.5 \times 63 \times b,$$

Whence

$$b = 0.66 \text{ ft.} = 8 \text{ ins., nearly.}$$

The vanes should curve forward at the inner end to make an angle with the tangent, of which the tangent, $\frac{v_1}{u_1} = 1.31$,

or the angle $= 52° 45'$.

The theoretic horse-power of such a fan would be

$$\frac{W\,Q_a\,v^2}{2\,g \times 550} = 8, \text{ nearly.}$$

Fig. 33 is drawn to scale showing the dimensions as just computed. The vanes and the hollow wheel in which they are inserted can best be made of sheet metal polished inside and outside.

The curved approach to the inlet should not be omitted. Judging by similar conditions in hydraulics, the discharge will be about 50% greater with a curved inlet than without. Hence, evidently, this is one of the most important details.

Adjustment.—The joint, *d*, is open to the atmosphere. When the wheel is designed and speeded according to principles already discussed, the energy passing the joint, *d*, is all kinetic, so that there is no tendency to leakage inward or outward. However, in most cases in practice, the resistance to be overcome in forcing air through the passage (pipe, mine, tunnel, building, furnace, or the like) cannot be computed accurately, and may vary from time to time. Hence, in order to meet these conditions satisfactorily, it is desirable that the fan should be adjustable. In order to understand this phase of the subject, the following discussion is necessary:

If all effects of compression are neglected, which may be done under the ordinary conditions of practice, the resistance to be overcome when forcing air through a passage, in which the conditions are constant,

will vary with the square of the velocity (proved by experiment), and, of course, the velocity varies directly with the quantity of air passed. Hence the resistance varies with the square of the quantity. Also, from Equation *VIII*, it is seen that Q^2 varies with V^2, all other factors being constant; and, by Equation *VI*, V^2 varies with u^2. Hence, from the foregoing considerations, it may be said that the resistance varies with u^2; and, from Equation *XI*, the pressure head produced by the wheel,

$$H = \frac{v^2}{2g} = \frac{2u^2 + v_1^2}{2g},$$

showing that it is sufficiently accurate for the present purpose to say that H, or the propelling force, varies also with u^2, v_1 being comparatively small.

Thus it is found that a fan cannot be adjusted to a variable resistance by varying the speed only. The folly of attempting to do so will be still more apparent when it is considered that the necessary power to run the fan varies with the cube of the speed, if it has a free discharge.

The problem of adjustment, then, is reduced to this: Either change the resistance by changing the quantity of air delivered without changing the speed, or change the speed (and thereby the propelling force) without changing the quantity; or possibly, both may be changed at once. In any case, it would be necessary to make the area of the air passage adjustable. Theoretically, the adjustment ought to be made in the area of the discharge passage from the wheel; that is, b, in the equations, should be adjustable; but, practically, it is very doubtful if the advantage would outweigh the disadvantage of mechanical complications necessary to provide for such adjustment. The discharge could be adjusted as in the adjustable pump.

The area of the inlet could easily be throttled to any extent, and some provision to do so may be found advantageous, though, theoretically, it is not the proper place to apply the adjustment.

Attention should be called to the fact that the conditions at the joint, d, will indicate to the attendant whether the speed and volume of discharge are properly related to the resistance, that is, if air is escaping at d, the resistance is too great, or the wheel is discharging more air than it can force through the passages; while, if air is being drawn in at d, the resistance is less than the wheel could overcome, or the wheel could send more air through the passages.

The writer suggests that, until experience throws light on this part of the study, the area of the discharge slot be made a little less than computed. Then, by speeding up, the required quantity can be obtained, and there will be some excess of propelling head. Without this suggestion it is probable that the designer would suppose that in order to be on the safe side both area and speed should have some excess.

Fig. 34 represents a fan in which the vanes are open on the side, and turn within a fixed casing. Otherwise, the proportions should be worked out as for Fig. 33. This construction is not as simple or as economical as that shown in Fig 33, though it represents present practice more nearly. Nor would it indicate whether the proportions and speed were properly adapted to the resistance. However, an orifice through the casing, as at y, on the line of least width, would give the needed indications, provided the proportions are in accord with the method described on pages 528 to 530. The idea is apt to prevail that by closing up the sides of the fan, as in Fig. 34, the air is kept in the passage and forced to move on into the conduit; but this would be an error, for if the propelling head, $\frac{v^2}{2g}$, and the possible volume are not properly related to the resistance, any excess of volume will not enter the fan. Attention to this fact will explain the paradox that, within assignable limits, the more open the passage in a mine the more power is required to run the fans. Close the passage, and no air passes. Then, though the fan continues to run, it discharges no air, and the power required is only enough to overcome the friction within the fan. This is one extreme. The other is, when there is no resistance outside the fan.

Testing Centrifugal Pumps.

Unfortunately, the published data taken in testing centrifugal pumps are incomplete in every case that the writer has examined. The only object in making the tests seems to have been to see if the pumps met the conditions of the contract. That, of course, is the most important matter, as far as a single pump is concerned, but what are most needed are comparative results as affected by variations in proportions, angles, speed and head. It is only from such data that we can interpret results intelligently and detect the combinations that give the best results.

The data which should be recorded in a test are:

First.—All dimensions and details of the water passages, including:

(*a*)—Suction pipe; length, diameter, valves, etc.;

(*b*)—Curves of entrance to the wheel, and details of the joint between the wheel and the casing when the runners are inclosed;

(*c*)—Angles (Δ and β) of the intake and discharge ends, respectively, of the propellers, with a tangent to the circle in which they move;

(*d*)—Details of the open joint between the runner and the casing at the discharge, when inclosed runners are used;

(*e*)—Details of the curve, if any, through which the water passes from the tips of the propellers into the "volute";

(*f*)—Dimensions of the "volute";

(*g*)—Conditions of the various surfaces as to polish.

All the above can be shown by two sections; one through the center in the plane of revolution, the other through the center at right angles to the plane of revolution. Dimensions should be shown in figures.

Second.—The pressures at three points, *a*, *b* and *c*, should be recorded, as follows:

(*a*)—In the suction, as near as possible to the wheel, but on a straight pipe or channel;

(*b*)—At the outer tip of the propellers, by tapping through the casing at right angles to the plane of revolution;

(*c*)—In the first straight section of the discharge pipe;

(*d*)—Relative elevations of the gauges at *a*, *b* and *c*.

Care must be taken to place the gauges where centrifugal force will not affect the results. When the gauges are set thus it will not be necessary to take the elevations of the water surface in the sump and discharge.

Third.—(*a*)—Speed, or revolutions per minute;

(*b*)—Water delivered;

(*c*)—Power consumed when discharging;

(*d*)—Power consumed with pump full of water, but without discharge;

(*e*)—Power consumed when pump is running empty.

Fourth.—The following points should not be overlooked in preparing for and in conducting a test:

(*a*)—The pump cannot start a discharge under a head that it can

maintain after starting. Hence, a valve discharging under low head should be provided.

(*b*)—It will seldom be found practicable to deliver the water to a stand-pipe with the desired head, especially when it is desired to vary the head, as will usually be the case. Then the only recourse is to throttle the discharge beyond the pressure gauge in the discharge pipe. In doing this, remember that with the discharge cut off entirely the maximum pressure head will be $\frac{u^2}{2g}$, including suction, and, as the valve is gradually opened the pressure head will rise, theoretically, to a maximum of $\frac{u^2 + u\,V \cos.\,\beta}{g}$, including suction head, after which, if the valve be opened further, the head will become less. Thus a skilful manipulation of the throttle valve while watching the pressure gauge should enable the operator to find the maximum lift for any speed readily. Theoretically, the condition that gives the greatest lift should also give the greatest efficiency. Practically, the greatest efficiency will probably be found when the valve is opened a little wider than when giving the greatest lift.

(*c*)—The total lift to be credited to the pump is the head shown on the suction gauge plus that on the discharge gauge plus their difference of elevation. The elevation of the gauges should be assumed at the surface of the water standing in the small pipe leading to the gauge, and some provision to determine this should be made.

APPENDIX.

While pursuing these studies, the following scheme for a hydraulic air-compressor occurred to the writer. It is a natural result of the ideas presented on pages 494 to 496.

Let *W*, Fig. 35, represent a centrifugal pump working in a closed circuit, *P Q R*, as shown; then, evidently, neglecting slight differences of elevation, the pressure in *Q* is equal to that in *R* (see also Figs. 11 and 18). How, then, can we account for the work done by the pump?

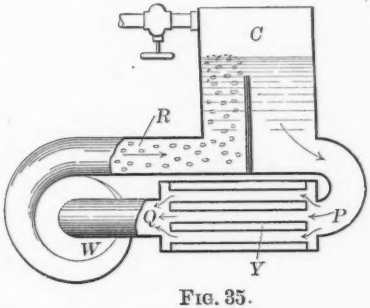


FIG. 35.

The answer depends on circumstances. For our present purpose we will assume an air space, *C*, somewhere in the circuit, and that free air has access to the joint, *d*, through the spaces, *n*, Figs. 11 and 18. Under these circumstances the rush of water through the flaring nozzle, *m*, into a relatively unresisting field (since the pressure in *R* equals that in *Q*) will cause a suction at the joint, *d*, and, assuming proper provisions for the admission of air, the entering air will be compressed to the pressure in *R* as soon as the velocity is checked.

The air thus compressed can be separated in a chamber, *C*, and thence conducted away. Theoretically (as the word is usually applied), we should find the energy in the compressed air equal to the work done by the pump, there being no other channel through which the energy can disappear except by friction in its various forms.

The water would absorb the heat of compression, and therefore isothermal conditions would be very nearly realized, but the heat thus absorbed would have to be taken out by exterior cooling, as suggested at *Y*, Fig. 35.

Another attractive feature in the scheme is that, theoretically, with nearly constant motive power and speed, the degree of compression can be varied indefinitely and the quantity of air entering will be self-regulating.

An easy computation will show that a compressor of great power and volume can be embodied in a small machine.

Disregarding cost, if mercury be used instead of water, the calculations show remarkable results.

If the air-chamber be abolished, or filled with water, and water, instead of air, be drawn in at *d*, we have a hydraulic jack of unlimited power.

The practical difficulties in carrying out such a scheme will probably be serious, and possibly insurmountable. To test it sufficiently to say whether or not it can be made a success would require extensive and expensive experiments. The main questions are: Can enough air be taken into the current to absorb the energy; and what is the best mechanical means for providing for its admission?

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

AN INVESTIGATION OF THE PROPERTIES OF BRICK, UNDER DIFFERENT PHYSICAL CONDITIONS.

Discussion.*

By E. J. McCaustland, Assoc. M. Am. Soc. C. E.

E. J. McCaustland, Assoc. M. Am. Soc. C. E. (by letter).—In conducting these tests, which show a great amount of painstaking labor on the part of Mr. Turrill, an excellent opportunity was offered to determine the rate, as well as the total amount, of absorption. With bricks heated for the time, and to the degree indicated in these experiments, and with the time allowed for the complete test, valuable information might have been obtained by weighing the bricks at frequent intervals during the period of immersion. Mr. McCaustland.

There is little doubt that the rate of absorption is much greater during the first few hours of immersion than at any later time, although there will be increasing absorption for a long period.

In ordinary commercial work it is not usually convenient to extend the absorption tests over more than 48 hours, and sometimes not more than 24 hours. The latter time is rather short; but the writer believes that 48 hours gives sufficient time to indicate clearly the character of the brick and give results definite enough for all purposes of comparison. It is probable, in any case of building brick and most cases of paving brick, that at least 75% of the total water of absorption would be taken up during the first 48 hours of immersion,

* This discussion (of the paper by Sherman M. Turrill, Assoc. Am. Soc. C. E., printed in *Proceedings* for March, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. McCaustland.

and it is believed that this initial absorption affords fully as satisfactory an index of the character of the brick as would be obtained from a more extended test. Certainly, it is absorption in the first stages that is important to consider in ordinary brickwork where it is exposed to moisture. Brickwork under water is usually constructed of a material which will absorb only a very small percentage of its own weight.

The writer believes that tension tests of brick should receive more attention than has been given to them heretofore. In crushing tests of a large number of brick piers or columns, he has found that failure occurred invariably by splitting longitudinally, the individual bricks failing by tension, with little or no indication of crushing.

The author's conclusions, based upon the results of his tensile tests, concerning the comparative strength of natural, filled-with-water, and reheated bricks seem to be scarcely justified. It is true that on the twelve tests the average strength of the reheated bricks is highest; but it is to be noted that two of these specimens (Nos. 96 and 231) give abnormally high results. With these omitted, or scaled down to the next highest figure (No. 491), the average will be practically the same as for the natural brick. Comparing the "filled-with-water" and the "natural," it is to be noted that six of the latter give a higher value than the corresponding "filled-with-water," and on the whole set of twelve bricks the averages for the three conditions differ only 8 lbs.

It would seem to the writer more nearly correct to conclude that these tests do not establish any difference whatever in the tensile strength of these three classes of brick. The stresses due to bending, although not to be classed as tensile stresses, have some significance in this connection, and their averages indicate an excess of strength in favor of the natural brick. However, notwithstanding the extent of these experiments and the care with which they were conducted, they are not sufficiently numerous to warrant general conclusions.

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PAPERS AND DISCUSSIONS.

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THE FILTRATION WORKS OF THE EAST JERSEY WATER COMPANY, AT LITTLE FALLS, NEW JERSEY.

Discussion.*

By Messrs. Allen Hazen, J. P. A. Maignen, C. L. Harrison, J. Waldo Smith, R. S. Weston, G. C. Whipple, W. B. Fuller, L. L. Tribus, Langdon Pearse and John H. Gregory.

Mr. Hazen.

Allen Hazen, M. Am. Soc. C. E.—This paper is of unusual interest, as it represents a careful and scientific development of a method of filtration which has been used extensively in this country in a less perfected and developed form. This method is that commonly known as mechanical filtration, in distinction from the older type known as sand filtration, which has been used widely by European cities for many years, and more recently to a considerable extent in this country.

The water at Little Falls is free from excessive sediment, and is of a type for which sand filters would usually be considered preferable. For waters of the turbid type, particularly where the amount of sewage-polluting matter is not great, mechanical filters give better clarification than sand filters. Mechanical filters, because of their high rate of filtration, occupy less space and can be installed on sites which are not adequate for the construction of sand filters; and, apparently, it was for this reason that mechanical filters were selected in this case, although the removal of color, which is more complete in connection

*This discussion (of the paper by George W. Fuller, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Hazen. with the chemical treatment than is possible by sand filters unaided, was no doubt an important, although secondary, object reached by the selection.

As far as the clarification is concerned, there can be no question as to the treatment. The results secured, as shown by the records given by the author, are almost ideal. The point of greatest interest in connection with its operation is, whether it will remove the disease-producing properties with the same certainty that well constructed and operated sand filters do.

Most of our knowledge as to the improvement of the health of communities by filtering their water supplies relates to the changes effected by sand filters. Corresponding data for mechanical filters are as yet limited and unsatisfactory. The figures for bacterial efficiency given by the author promise much in this respect. It should be noted, however, that the raw water is much less polluted by sewage than the corresponding water in many places where sand filters have been used, as for example, at Poughkeepsie, Lawrence and Albany; and, as the author states, the death rates of the population supplied in the past with the water in its raw state have not been excessive. The test is thus a less searching one than would have been the case under other conditions, and, at the same time, the conditions left less room for doubt as to the outcome, from a sanitary standpoint, than would have been the case had the raw water been polluted by sewage to a much greater extent.

In a sand filter operating at a low rate of filtration, the removal of the disease-producing properties, which are, in general, the bacteria, seems to depend upon the attraction of the bacteria for the sand, and for the matters which accumulate upon the sand grains in the course of filtration; and that action, as we know, is such that the removal of the bacteria is most complete. In a mechanical filter the rate of filtration is increased, in a general way, forty times. The result of this increase in rate is that the actions which make the sand filter efficient are no longer adequate to remove the bacteria, and the action of the filter becomes dependent upon the addition of coagulant to the water before filtration, and the formation of a flocculent precipitate in it which entangles the bacteria and allows them to be removed at the high rate. The efficiency of the filter, in this respect, depends absolutely upon the faithful and continuous application of coagulant. The problem reduces itself to devising mechanical means for securing at all times the application of the coagulant to the raw water in the right amount. If this can be accomplished thoroughly there can be no doubt as to the efficiency of the purification secured.

There are a great many mechanical filter plants in the United States. Unfortunately, most of them have failed in this respect at times. In some of them the failures have been so frequent and extended as to

Mr. Hazen.

be habitual. Others have failed less frequently, but they have failed more frequently because the coagulant was not applied faithfully and continuously than from any other cause. In this plant a decided step has been taken in securing devices to insure the continuous application of the coagulant, as far as devices can be secured; for, after all, the human element is often the weakest link in the chain, and that cannot be eliminated altogether.

The probability of satisfactory operation is increased greatly by the laboratory which has been established in connection with the plant, where the operation is watched with care and in detail, and the results are recorded fully and impartially. This is a most important step in securing uniformly excellent results, and it is to be hoped that it will be followed in all important plants. The importance of such supervision is shown in the tables of results and by the fact, as noted by the author, that the lowest efficiencies obtained have followed the failure to secure perfect operation of the coagulating apparatus. Without the laboratory, these slight lapses would have passed unnoticed, and the improvements in the apparatus to correct them would not have been made.

A large part of our accurate knowledge of mechanical filtration has been derived from certain experiments made by the author at Louisville, Ky., and by the speaker at Pittsburg, Pa. In each case filters of what are known as the Warren and Jewell types, as well as certain other appliances, were installed. A comparison of some of the features of these earlier experimental filters with the Little Falls filters may be of interest. Some of the figures, necessarily, are only approximate.

TABLE No. 17.

	Little Falls filters.	Louisville Experimental Filters.		Pittsburg Experimental Filters.	
		Jewell.	Warren.	Jewell.	Warren.
Capacity of coagulating basin, in hours' supply, when rate of filtration is 125 000 000 galls. per acre daily	1.28	0.48	1.15	0.49	0.89
Depth of sand, inches	30	34	27	57	27
Effective size of sand, millimeters	0.40	0.43	0.51	0.46	0.70
Uniformity coefficient of sand	1.50	1.65	1.47	1.40	1.30
Diameter of holes in strainer system, millimeters	1.60	0.71	1.09	0.63	0.61
Percentage which holes in strainer system are of filter area	0.26	1.44	6.00	1.20	8.30

Mr. Hazen. The Pittsburg and Louisville experimental filters may be regarded, in a certain sense, as prototypes of the Little Falls filters, and it is interesting to note the changes from the earlier designs.

The coagulating-basin capacity at Little Falls is increased. Undoubtedly this change is most advantageous, and it may be questioned whether still further increase would not be desirable. The best size for the coagulating basin depends almost entirely upon the character of the raw water, and a size most advantageous for one water might be quite inadequate for another.

In the depth of sand there is but little change, although the very deep layer used in the Jewell filter at Pittsburg has not been repeated. The sand is slightly finer than in the earlier filters, but the change is not important, and the uniformity coefficient, which was insisted on rigidly at Little Falls, is about the same as in the earlier filters.

The size of the holes in the strainer system is much greater, but the total area of the holes is reduced. The large size of opening is only possible in connection with the considerable gravel layers at the bottom, and these layers are no doubt necessary with the smaller total area of the openings.

The ample area of the exit holes in the Warren filters has much to commend it. If the action of filtration was all that had to be considered, the size would hardly have been reduced below this figure. The disadvantage of the large strainers is in the washing. With them there is not sufficient control of the points at which the wash-water rises through the sand. The only way that this has been controlled adequately has been to restrict the sizes of the openings in the strainer system, until so much head is consumed in forcing the water through that a good distribution of the water is secured over the whole of the area. In the Jewell filters, this was secured by taking the water through necks immediately below the strainer outlets, these necks having an area of only approximately 0.07% of the filter area. This arrangement secured a very good distribution of wash-water, but was open to the objection of having an abnormally high friction for both the entering and leaving water.

In the Little Falls design, the holes in the strainers themselves represent the greatest amount of contraction, and the area of these holes, while much less than the area of the holes in the Jewell strainer systems, is three or four times as great as the area of the necks back of those holes.

The strainer system serves two widely different uses. In normal operation, it collects and removes the filtered water; in washing, it distributes the wash-water, and the distribution to all parts of the filter bottom must be substantially equal. The requirements of the two services are quite different, and the strainer system is a compromise

between the requirements of each. The speaker has often questioned in his mind whether the best possible results could be secured without using separate systems for the two services. Mr. Hazen.

The most important point of divergence from the earlier designs is the substitution of air for agitating the sand during washing for the rakes driven by power, which served this purpose in all the earlier filters. Air agitation has been used on many smaller filters, but not before where the results were actually recorded and made available for study by those interested in the art of water purification. The air agitation has the advantage, in its ready applicability to rectangular masonry filters, and in avoiding the necessity of having power and shafting over the filters. It seems to work well at Little Falls, and the present indications are that it may largely supersede other forms of agitation.

The excellent manner in which concrete has been used in all parts of the design is most creditable to the constructing engineers.

J. P. A. MAIGNEN, Assoc. Am. Soc. C. E.—The expression "ripening" of filters has been used by Mr. Fuller, and the speaker would like to ask him and Mr. Hazen what, in their opinion, is meant by it. Is it that the surface of the grains of sand becomes more or less covered by water bacteria, and do these bacteria help the act of purification in any other way than by blocking the interstices between the grains of sand; or, on the contrary, are we to understand that a sand filter becomes "ripe" or capable of giving a good bacterial effluent when the sand has been deprived of the air germs it contained before any water had been passed through the filter? In other words, does the "ripening" imply the addition of water bacteria to the sand, or the elimination of air germs from the surface of the sand grains by a more or less prolonged flow of water? Some light on this subject might not be without interest. Mr. Maignen.

This brings us back to a statement made by the speaker in discussing the topic "The Decolorization of Water,* when he cited some experiments he had made during several months with filters containing granular materials—sand and charcoal. In both cases practically sterile water was applied (from 8 to 20 bacteria per cubic centimeter). The effluent, during the first two or three days, had from 100 to 300 bacteria per cubic centimeter, and, day after day, although the applied water was always the same (not averaging more than 15 bacteria per cubic centimeter), the filtrate went on showing an ever increasing number of bacteria, until the fifteenth day, when it had reached upwards of 5 000. Then the number of bacteria in the effluent began to fall off, until, at the end of the month, the filtered water did not contain more than the applied water (about 15 bacteria). Therefore, it took one month to "ripen" these filters. They were kept in opera-

* *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 168.

Mr. Maignen. tion for more than three months afterward, and during all this second period—that is, after the filters had been "ripened"—the applied water never contained less than 2 000 bacteria, sometimes it contained 5 000 or more, and the filtered water never contained more than 20.

How can the large number of bacteria found in the filtered water during the first fortnight be accounted for? It cannot be, as has sometimes been said, that the granular materials are favorable to the development of water organisms introduced with the applied water, because, in this case, the applied water was practically sterile. If the theory of the multiplication of the bacteria in the filter were attributed to the accumulation of mud, how was it that, all of a sudden, and forever after a certain time (nothing being done to sterilize the materials), the number of bacteria in the filtered water went on diminishing daily until it became as low as in the applied water and continued practically sterile for months, although the applied water after the first month contained a very large number of bacteria?

A plausible explanation is to be found in the fact that when granular materials—sand or charcoal—are new the grains are surrounded with dust partly made up of dry germs. These dry germs may be compared to dry seeds, which, as pointed out by Tyndall, when in contact with water, are softened and incubated, as it were, and they become full-grown bacteria. In this state of life they either go out with the filtered water, or die in the sand without progeny.

The speaker, therefore, suggests that the true explanation of the "ripening" of filters is to be found in the gradual elimination of the original or "constitutional" germs existing in materials which have been exposed to the dust of the air previous to being used in filters.

Some of the speaker's experiments would appear to strengthen this view. One of the sand filters which had been "ripened," as already explained, and was giving perfectly pure water during more than one month, was placed out of service, the old sand was carefully taken out and a thin layer of small pebbles, which had not been washed or used before, was placed at the bottom of the filter, and the old "ripe" sand put back again over the pebbles. During the following days the filtered water became very rich in bacteria, and it was more than a fortnight before the filtrate was as free from bacteria as the applied water.

The ripening of filters, therefore, would seem to consist in freeing the sand from air germs and not in charging it with water bacteria. This is but an idea, for which the speaker has given his reasons, and it is submitted for consideration.

Mr. Harrison. C. L. HARRISON, M. Am. Soc. C. E.—This paper presents the modern design and construction of the mechanical filter, and is a valuable addition to the literature on the subject of water purification. The construction is substantial and cleanly, and the design is in accordance with the best recent knowledge of this subject.

Mr. Harrison.

There is one marked difference between the design of this plant and of those which were constructed a few years ago. In the older plants the coagulant was introduced directly into the filtering tanks, while in this one it is mixed with the raw water, which is then allowed to pass through a subsiding basin, from which it is taken to the filtering tanks. This is an important feature of the design, as Table No. 4 shows, for the months of October, November and December, 1902, and January, 1903, that 83, 68, 67 and 58%, respectively, of the bacteria in the raw water were removed before the water left the subsiding basin; and, in addition to this, the sludge is deposited in this basin, instead of in the filtering tanks, where it would clog the sand and necessitate more frequent washings. Some experiments made by the speaker a few years ago show clearly the great value of the subsiding basin, and indicate that one large enough to require more than one hour for the water to pass through it would be desirable. The effect of the basin would be increased very much by taking the water from it at points near the surface. The plans do not seem to indicate how this is done, and perhaps the author will give some further information on the subject. By using a subsiding basin of proper size, the action of the coagulant can be entirely completed before the water reaches the filtering tanks, and the sludge be deposited in the basin, thus increasing the efficiency of the plant in removing the bacteria and reducing to a minimum the quantity of wash-water required.

Mr. Smith.

J. Waldo Smith, M. Am. Soc. C. E.—Since the end of the six months' experimental period mentioned in the paper, there has been one month of normal operation of this filter plant. During that month—March, 1903—the quantity of coagulant was about 15% in excess of the expected average.

The average quantity of wash-water has been about normal; and the plant has been operated at about one-third of its normal capacity.

The cost per million gallons of filtered water delivered into the pipes (wash-water deducted) has been as follows:

Labor	$1.22
Coagulant	1.60
Heat	0.25
Power	0.12
Total	$3.19

If the quantity of water filtered was twice as great as at present, the labor item in the above cost would not be increased. The cost of coagulant would be in proportion to the quantity of water filtered, and the heat and power items would be increased only slightly. In fact, the heat item for March is greater than the average per month throughout the year.

Under these conditions, which will probably obtain within a year, the cost per million gallons would be about $2.50, instead of $3.19, as stated above.

Mr. Weston. R. S. WESTON, Assoc. M. Am. Soc. C. E.—This excellent paper presents few points which can be criticized unfavorably.

Passing by the discussion of the construction of this intricate monolith, and considering the operation of the plant, one is impressed by the care taken in the design to have everything convenient for the operator. Those who have had to do with the operation of rapid filters have been impressed by the great loss of time and consequent cost incurred for the opening and closing of valves during the washing of the sand layer; but when one goes to Little Falls and sees how easily the filters are operated, how little labor is performed to obtain the required results, he is filled with admiration for the work.

The speaker has made several visits to Little Falls, both during the construction and during the operation of the filter plant, and he doubts if any municipal structure, built during the last few years, has had in it so few things which have had to be changed after the completion of construction, notwithstanding that the Little Falls construction represents many new departures.

The chief of these departures—the use of air as an agitator, during the washing process—permits the rectangular construction of the filter tanks, thereby enabling one to increase the size of the units (tanks) and to abandon the short-lived mechanical agitator and the space-consuming, round filter tank.

The speaker happened to be in Little Falls before the gravel was put into the filters, and while the air and water distribution systems were being tested. The efficiency of these devices was excellent. The water appeared at every strainer at about the same time, and the spray from the strainers appeared to cover the whole bottom of the filter, when viewed from above. The air, also, was well distributed.

The gain in efficiency at Little Falls due to the use of air agitation is well shown in the tables. Whether this agitation by air or by means other than water currents is necessary in all filter plants—that is, enough to justify its cost—is a question. The water at Little Falls might be called fibrous. It contains much vegetable and amorphous matter, which makes a felt on the sand layer during filtration, and which must be removed continuously with each washing, in order to maintain the sand layer at its highest efficiency. The use of air agitation breaks up this felt and the concretions of aluminum hydrate, amorphous matter and sand, and reduces all the matter to particles of such a hydraulic value that they can be removed more readily, subsequently, with the wash-water. Whether agitation would be necessary with a water containing only crystalline, silty and finely divided suspended matter (which does not seem to form a mat or felt on the surface of the filter), and where the expense of the agitator is a consideration, must be left to the future and to the larger plants for its solution.

Mr. Weston.

Certainly, the experience which will undoubtedly be gained from the operation of this plant will establish the system of rapid filtration upon a firm, rational and scientific basis, and it must be felt by all that, at least after the proposed plants at Louisville, Cincinnati and New Orleans are completed, it will be possible for engineers to design rapid filters with little or no chance of failure, provided all the local conditions are studied carefully.

Regarding the preparation of sand for a rapid filter, the speaker agrees with Mr. Fuller that it is necessary to have a uniform sand, of medium size, practically free from particles finer than 0.25 mm. in diameter. To obtain sand of this character is a hard task. Of late the speaker has been attempting to devise an apparatus for the removal of the fine particles, the "dust," from a lot of sand. This means that all particles which would pass through wire-cloth with 80 meshes to the linear inch must be removed. Given, dry sand, it is a simple problem to separate particles which would pass through a screen with 60 meshes to the inch, but a much more difficult one if finer screens are tried.

Thinking that, perhaps, the best method was to dry the sand and pass it through a screen, the speaker designed a hexagonal rotary screen, 4 ft. in diameter and 9 ft. long. The frame of this device carried two concentric, hexagonal, wire-cloth screens, the inner of No. 20 and the outer screen of No. 80 mesh. The screen made about thirty revolutions per minute. It was cleaned, from the outside, by a jet of compressed air.

The sand was heated to a temperature of from 300 to 400° Fahr., and was thoroughly dry. It was then fed into one end of the screen at the rate of about 22 cu. ft. per hour. The results were unsatisfactory. The fine screen clogged quickly—so quickly, in fact, that it became useless after a few days. For the first three or four days, with constant watching, one could get proper sand at a cost of about $10 a cubic yard; and, by the way, $10 a cubic yard is not a high estimate for rapid-filter sand. At present a winnowing-device is being tried; the first work is satisfactory, and the cost of operation reasonable. It is hoped that the solution of the problem lies along these lines, as separation by hydraulic means is practicable only where water is cheap and abundant.

This paper reflects great credit on its author, his associates, the filter company and all others concerned in the design and construction of this excellent work.

Mr. Whipple.

GEORGE C. WHIPPLE, Assoc. M. Am. Soc. C. E.—The speaker has been privileged to follow the construction of the Little Falls filter plant from the beginning, and to witness its successful operation. To say simply that it is a success would be faint praise, indeed. It is the first adequate demonstration of the principles of mechanical filtra-

Mr. Whipple. tion applied on a large scale, and its many unique features distinguish it sharply from the conventional type of mechanical filters used heretofore.

Among the features which have interested the speaker especially are those which appertain to the filter proper, namely, the sand, the gravel, the strainer system, and the application of compressed air as an aid in sand washing. These details seem to have been arranged with great care, and, in themselves, are sufficient to render this plant unique.

The fact that so little sand has been lost during the washing process is proof, not only of delicate design, but of careful operation. This fact appeals to the speaker all the more strongly, perhaps, because he has recently had experience with a mechanical filter in which the quality of the sand was poor and the method of sand-washing was imperfect. In this plant the compressed air and wash-water were applied to the bed simultaneously, with the result that in a short period of a few months' time so much fine sand was lost that the effective size increased from about 0.30 to about 0.60. It is certainly more scientific to use sand of a proper size and adjust the wash-water conditions so that no sand may be lost than it is to use a cheap, improperly graded sand and depend upon the wash-water to remove the fine material.

The speaker agrees with those who have already spoken that it is a matter for congratulation that the Little Falls filter has been tested so carefully. While many data are available for experimental plants, there are comparatively few mechanical filters which have been tested adequately. It is only by the publication of such results that the popular prejudices against mechanical filters can be swept away. Take, for instance, the matter of alum. The speaker supposes that there is no engineer who has recommended the installation of a mechanical filter but has had to contend with the popular prejudice against the use of alum, and who has not been told, in cities where such plants have been installed, that the consumers could taste the alum—sometimes even before it was used.

The fact that it is possible to prevent undecomposed alum from passing through a mechanical filter, even though the alkalinity of the original water be low, is demonstrated by the five thousand tests which have been made at Little Falls. This is something to which engineers can "point with pride," and the operators can take as much credit for this as the engineers. Indeed, it cannot be stated too emphatically that the successful operation of a mechanical filter is dependent upon the conscientious and unflagging attention of the operators, night and day, day in and day out. No mechanical filter will run itself. Even automatic devices must be watched. But, while the element of human fallibility is introduced in the operation of a me-

chanical filter, more, perhaps, than in the case of a sand filter, it must be remembered that locomotives and steam pumps and boilers need to be watched, and so does every form of machinery. It is no more difficult to care for a filter than to care for pumping machinery, and, with the same class of operators and with suitable filters, periods of imperfect filtration ought not to be more common than railroad accidents. Just as the country has developed a class of men skilled in firing boilers and running engines, so there must be developed a class of men skilled in operating filters. At the present time there is no more promising field for a young graduate engineer than that of superintending the operation of filter plants. Such men need to have some knowledge of chemistry and bacteriology—enough for them to carry on certain simple tests of the water before and after filtration—and they should understand the principles of hydraulics and be of a mechanical turn of mind. It is hoped that our engineering schools will take this subject into consideration and see that their students have proper instruction in the operation as well as in the design of filters. Mr. Whipple.

WILLIAM B. FULLER, M. Am. Soc. C. E.—As Mr. Hering has well stated, the completion of this plant stands as a milestone marking a distinct progress in the art of mechanical filtration. In a lesser, though still distinctive, way it stands as a milestone from a constructive point of view, in that it has been constructed throughout almost entirely of concrete. This has been done with an idea of making the entire structure as durable and permanent as possible, and it is this part of the work to which the speaker now wishes to refer. Mr. W. B. Fuller.

The substructure of the plant, that is, the portions acting as coagulating basins and clear wells, is built as a gravity section of concrete in mass, without iron. The filters over the clear well, the walls of the building proper, and of the monitor, are also built of concrete, with steel rods embedded throughout the mass. All floors and partitions, as well as the benches and chemical hoods in the laboratories, stairways between different levels, mixing, solution and chemical tanks, and columns and girders throughout, are also of concrete construction.

In relation to this construction there are a number of unusual features. The floor over the coagulating basin is designed for a load of 350 lbs. per square foot, and consists of two spans of 24 ft. each, the interior ends of the floor beams resting on concrete girders, resting in their turn on concrete columns from the bottom of the basin 43 ft. deep. These columns average 42 ins. square, and sustain an exterior load of more than 10 tons per square foot. This is possibly as tall a column for sustaining such loads as has yet been constructed of concrete. The floor of this basin, while designed to carry 350 lbs. per square foot, has frequently to carry a loaded cart, the concentrated load on each wheel being about 1 500 lbs.

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In one portion of the plant there are two mixing tanks, which are 16 ft. in diameter and 16 ft. high, containing about 25 000 galls. of water each. They are round tanks, made of concrete 12 ins. thick, the concrete surrounding an iron skeleton. These tanks are tight and safe with water inside pressing outward or with water outside pressing inward. They are also set upon the top of concrete posts, about 30 ft. above the floor of the coagulating basin.

The stand-pipe, or tank into which the river water and the coagulant first enter, is 10 ft. in diameter and 43 ft. high, and it is tight with a water pressure either inside or outside. It is made of concrete, 15 ins. thick at the bottom and 10 ins. thick at the top, the concrete being reinforced with iron rods embedded therein. This entire tank was built in 8 hours, all the concrete being placed from the top, and thus falling the full depth of 43 ft. when the tank was first started. This is contrary to the ideas of a great many engineers in regard to proper concrete construction, that is, to put in a depth of 43 ft. of concrete continuously without stopping.

This concrete was put in very wet, a wheel-barrow load (5 cu. ft.) at a time, and was merely joggled to position. When the forms were removed the surfaces were absolutely smooth, not a stone or a void showing. It had been intended to plaster the inside surface of this tank to make it water-tight, but the plastering was omitted as being wholly unnecessary.

An interesting part of the construction is the suspending of the steel pipes, 66 ins. in diameter, and full of water, from stirrups fastened to the concrete floor beams.

These pipes when full weigh more than 1 ton per linear foot, and convey the water from the coagulating basin to the filters; for a part of their length they are protected inside with a cement lining.

The filters themselves, of which there are thirty-two, were built under a guaranty as to tightness and strength, the minimum sections of concrete and metal having been specified before bids were received. As these tanks are situated directly above the clear-water basin, it was essential that they should be absolutely water-tight. This result was secured, as a trip around the clear-water basin in a boat failed to detect any dripping from the filled tanks above. This result was secured first by building each tank as a monolith, the bottom, sides, and top, all at one continuous operation. They thus became for all intents and purposes like a nest of boxes, each box being free to move by itself under varying stresses. Each tank was also plastered on the inside first with a $\frac{1}{4}$-in. coat of 1 to 1 cement-and-sand mortar and then a $\frac{1}{8}$-in. coat of neat cement mortar. This last coat, below the sand level, was stippled with a stiff corn broom, so as to make the surface very rough, to prevent the passage of water between the sand and concrete sides, rather than through the sand.

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The concrete in the lower part of the structure was made in the proportions of 1 part cement, 3 parts sand and 7 parts stone, which are rather unusual proportions for water-tight work under heads up to 43 ft. The idea, when the specifications were made, was that it would be best to make a water-tight lining on the inside of the basins with a very rich concrete, and make the outer part of the wall with a poorer concrete, in order to save cost, the theory being that if the inner lining leaked, it would be best to have such water pass out through the back of the wall.

In actual construction, however, it was found that the 1 : 1¼ : 3 concrete—the very rich concrete—which was used for the lining, was very difficult to place, and, as placed, it actually was not as tight as the 1 : 3 : 7 concrete. The latter was absolutely water-tight, as far as permeability is concerned. What leaks there are in the plant are very few, and they have always occurred in joints or at cracks due to temperature. A great deal of care was taken in the grading of the sizes of the sand and stone, so as to have the voids filled very thoroughly before any cement was placed in the mass.

Mr. Tribus.

L. L. TRIBUS, M. Am. Soc. C. E.—It seems that the past has demonstrated that filtration can be effective for the almost absolute removal of sedimentary and deleterious organic matters in public water supplies, and it is also fully evident that many surface-water and some ground-water supplies, as well, will soon have to be filtered.

There can be no question that with proper care either the "rapid" or "mechanical" process, or the "slow" or, as ordinarily described, "sand process," will be effective; one being, however, more of a straining method, the other probably more thoroughly bacteriological, and so, perhaps better, from a strictly sanitary standpoint.

An interesting question, not largely investigated as yet, but to which special attention should be given at an early date, is whether water treated by the "rapid" process will keep longer in storage without spoiling than that treated by the "slow sand process" (the chemicals generally used with the former ought never to be in such excess as to be in themselves a factor). Thus far, it has been deemed most expedient to keep all filtered waters in covered storage reservoirs and in relatively small quantities at that, but as filtration comes into more general use it will be found, in many instances, very desirable to have the processes carried on near the sources of supply, and the filtered water delivered to existing large open reservoirs near the point of use. If all filtered water is going to deteriorate seriously with such "open storage" more rapidly than would unfiltered water, then filtration has not yet reached the point of development which it must reach for universal application. If the same water will keep longer in good condition after being filtered by one of the main processes, then that process will control the general situation.

Mr. Tribus. At the plant under discussion, test analyses of the raw water, the water in the coagulating tank and in the filtered-water basin, have been made systematically, with, perhaps, a few analyses of the water from the tap as delivered some miles away. The results seem to have been eminently satisfactory, but what would the result be if this same water, prior to its use, should be stored for several weeks after filtration, in an open reservoir? The question can only be answered by experiment, and it is to be hoped that such test, along the line suggested, will be made by the company whose plant has been so well designed and so interestingly described by Mr. Fuller.

Mr. Pearse. LANGDON PEARSE, Jun. Am. Soc. C. E. (by letter).—There is one point in Mr. Fuller's admirable paper which is not clear to the writer. He has been unable to find any statement concerning the co-ordination of the rate of application of the alumina sulphate solution to the flow of raw water through the "alum" grid. To vary the application of the alum solution properly, some device is needed. In the writer's brief experience with a small municipal filter plant, a case occurred where the quantity of alum added to the raw water was entirely too small, simply because of the impossibility of measuring the flow of the raw water as it passed the outlet of the alum feed. The alum had to be regulated by the pumpage from the clear-water well, which by no means corresponded to the flow of raw water into the settling basin during the same interval.

Mr. Gregory. JOHN H. GREGORY, Assoc. M. Am. Soc. C. E. (by letter).—Thanks are due, not only to Mr. Fuller for his valuable paper on the Little Falls Purification Works, but also to Mr. J. Waldo Smith, Superintendent and Engineer, and to the other officers of the East Jersey Water Company, for allowing the publication of such a complete description of the plant, and especially of the results accomplished during its first few months of service. The writer knows of no place where so much valuable information requisite for designing a mechanical filter plant properly is available as is given in condensed form in this paper.

The writer visited the construction work several times during its early stages, and was fortunate enough to be located so that he could visit the plant frequently during the latter part of the construction, as well as since it has been put in service, and he has made the most of these opportunities to study the construction and operations in detail. The type of construction adopted at Little Falls is radically different from that used heretofore for mechanical filter plants, and, in the opinion of the writer, is a great improvement over that used for certain other plants built recently. The design of mechanical filter plants in the future will, it is to be hoped, be modeled, in general, closely after the Little Falls work.

The writer is a strong believer in very wet concrete, and it is

Mr. Gregory.

especially interesting to note that the concrete in the main construction at Little Falls was mixed so wet that the workmen had literally to wade through it. Concrete thus mixed requires very little tamping, rather a joggling of the whole mass into position, and the engineer can feel assured that he will get a satisfactory piece of work, and that when the forms are taken down the exposed faces will present a smooth appearance and be free from voids. This smooth appearance was characteristic of the work at Little Falls. Although it is impossible now to inspect very much of the heavy walls, yet certain portions are still exposed, namely, those shown below the superstructure in the views on Plate XVIII,* and a visitor to the plant who is interested in concrete construction will be well repaid by examining these walls carefully. They have not been touched in any way since the forms were first taken down.

It is common practice in filter construction to take certain precautions to prevent the raw water from passing down too rapidly alongside the walls. At Little Falls, as has been stated, the inner walls in the filter tanks below the sand surface were roughened by stippling with a wire brush before the plastering had set. The surface thus produced was very rough, and, in fact, for the end desired, was the most satisfactory surface which the writer has ever seen.

In designing the concrete walls and piers for the slow sand filters at Philadelphia, the writer advocated a slightly different method of procedure. The exposed faces of the piers and walls below the sand line were to be floated with a thin plaster of Portland-cement mortar, and then, before this plaster had set, were to be dashed with sand. The necessary clauses providing for this were inserted in the specifications. After the construction was under way, of course the attempt was made to carry out this provision of the specifications. The writer was not in charge of the construction, but visited the work frequently to watch its progress and the methods used by the contractors. The sanding of the surfaces, as actually done, could hardly be said to be satisfactory, but, in the opinion of the writer, this was due entirely to the method of doing the work. The writer had seen surfaces elsewhere which had been finished rough by being dashed with sand, namely, the coping and exposed faces of small concrete retaining-walls, and surfaces similar to these the writer had in mind when the specifications were written. Recently, he has heard that the attempt to sand these surfaces has been abandoned, and that they are finished smooth, but trusts that he has been misinformed in this particular. In his opinion it would be much better to leave the rather rough surface produced by the common wooden float than to trowel them smooth; or, better still, to roughen them by stippling with a wire brush, as was done at Little Falls.

* *Proceedings*, Am. Soc. C. E., for February, 1903, p. 171.

Mr. Gregory.

The idea of using hydraulic valves instead of the ordinary hand-operated valves was a happy one, and, at a glance, will be apparent to anyone who can watch the daily operations at Little Falls and at other plants. The ease with which the valves are controlled was brought home to the writer very forcibly a few weeks ago. He had occasion to conduct a series of experiments at a mechanical filter plant in which it was necessary to open and close a valve at frequent intervals to control the supply of water. The valve had the ordinary hand-wheel, and it turned very hard, as the stem was bent slightly.

All took turns at handling the valve, and the time and labor consumed was anything but pleasant, to say nothing of the comments which were forthcoming.

The use of air for agitating the sand layer has proved successful. Many times the writer has watched the application of air to the various tanks, in the ordinary operations of washing, when the tanks have been only partly filled with sand, and with no sand when the strainers have been covered with only a few inches of water. When the air is turned on, it naturally finds a relief through the nearest outlets, and the thought passes rapidly through one's mind, "Will it come out all over the bed?" But this is answered at once by the almost instant agitation of the water surface at all points, and, as far as the eye can judge, with a perfectly uniform distribution.

The experiments indicate that at Little Falls the use of air for agitation, in addition to that produced by the wash-water, is of advantage; but it may be that at some other place, with a different water, the air could be dispensed with, reliance being placed on the wash-water alone. Engineers, however, would hesitate to design a plant to operate under such conditions without first having demonstrated its feasibility by a series of carefully conducted experiments.

The Little Falls plant is thoroughly up to date, but experience indicates that here, as with nearly all work, improvements can be made. In the case in question, however, they are entirely of a minor nature, and do not affect the work as a whole.

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PAPERS AND DISCUSSIONS.

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DEFLECTIONS OF BEAMS WITH VARIABLE MOMENTS OF INERTIA.

Discussion.*

By Irving P. Church, Assoc. Am. Soc. C. E.

Irving P. Church, Assoc. Am. Soc. C. E. (by letter).—The author has presented a derivation of the "Fraenkel Formula," Mr. Church.

$$\triangle = \int_o^l \frac{M m \, d\, x}{E\, I}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

which seems to the writer to be lacking in rigor; or at least would probably be so considered by a reader not familiar with the books on "Least Work" by Castigliano and Martin, and who, therefore, might be unable to "read between the lines."

For mathematical purposes, an auxiliary force is supposed to be applied to the beam at the point whose deflection is desired, in addition to the actual loading. Now, this force should ultimately be reduced to zero (as in similar demonstrations by Castigliano) before a result can be reached that will be rigorously applicable to the beam under actual loading alone. Such an ultimate reduction to zero is presumably implied by the author in the evident assumption that the effect of the bending moment due to the auxiliary force in the production of the change of length, λ, in fiber, is negligible. Strictly, if M' denote the bending moment due to the auxiliary force alone, we should have

$$\lambda = \frac{(M + M')\, y\, d\, x}{E\, I}; \text{ instead of } \frac{M\, y\, d\, x}{E\, I}.$$

* This discussion (of the paper by C. W. Hudson, M. Am. Soc. C. E., printed in *Proceedings* for March, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Church. To ignore the M', then, when added to the M (moment due to actual loading), is to anticipate the final reduction to zero of the auxiliary force. But in the demonstration, as presented by the author, the auxiliary force used is one of unity, which, of course, cannot be reduced to zero; and nothing is said as to any change of value on the part of this force.

To the writer, this obscurity seems entirely unnecessary, and he would suggest the following changes in the details of the argument: Let the auxiliary force at the point in question have a value of Q units; and let $\triangle'$ be the deflection, in the direction of this force, of the point of application; as due to the combined action of Q and the actual loading.

Under these circumstances, if M' is the bending moment at any section as due to Q alone, the final stress in any fiber, as due to Q alone, will be $\frac{M'y}{I}$; and hence, eventually, the internal work due to Q alone, in the simultaneous and gradual application of both Q and the actual loading, will be, for the whole beam

$$W = \int_o^l \frac{(M + M')\, M'\, d\,x}{2\,E\,I}; \quad \ldots\ldots\ldots\ldots\ldots\ldots (1a)$$

while the external work of Q will be

$$W' = \frac{Q\,\triangle'}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2a)$$

Equating these values of W and W', we have

$$\frac{Q\,\triangle'}{2} = \int_o^l \frac{(M + M')\, M'\, d\,x}{2\,E\,I}.$$

If, now, we define a quantity, m, as being the rate at which Q produces the bending moment, M', in any section; in other words, if we state that the value of M' is at the rate of m foot-pounds moment for each pound (or other unit) in the value of Q, we may write $M' = Q\,m$; whence

$$\frac{Q\,\triangle'}{2} = Q \int_o^l \frac{(M + Q\,m)\, m\, d\,x}{2\,E\,I} \quad \ldots\ldots\ldots\ldots\ldots (2b)$$

In this expression it is to be specially noted that m is a function simply of the position of Q (being numerically equal to the bending moment that would be produced at any section by a force of unity at the point in question), but that it is not a function of the magnitude of Q.

Equation 2*b* may now be written

$$\triangle' = \int_o^l \frac{(M + Q\,m)\, m\, d\,x}{E\,I}, \quad \ldots\ldots\ldots\ldots\ldots\ldots (2c)$$

and is evidently available for determining the deflection of the point of application of Q, in direction of Q, as due to both the original load-

ing and the force Q itself; Q having any value. If, now, Q be made equal to zero, the equation takes the form Mr. Church.

$$\triangle = \int_o^l \frac{M\,m\,d\,x}{E\,I}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

the quantity, m, retaining its first value, since it is independent of the magnitude of Q, while $\triangle$ denotes the deflection of the point in question, as due to the original loading alone. In this way it would seem that all obscurity in the derivation of the "Fraenkel Formula" might be avoided. It can easily be shown, however, that Equation 2*c* is, after all, nothing more than an expression of the fact or theorem, proved by Castigliano and others, that the deflection or displacement (in the direction of the force) of the point of application of a force, Q, acting with other forces on an elastic beam, is equal to the derivative (or "differential coefficient") of the total internal work of the beam, with respect to the force, Q. For it will be noticed that, if M'' be used to denote the bending moment at any section, as due to all the loads, including Q (that is, let $M'' = M + Q\,m$), we have $\frac{d\,M''}{d\,Q} = m$; and hence Equation 2*c* becomes

$$\triangle' = \int_o^l \frac{M''}{E\,I}\left(\frac{d\,M''}{d\,Q}\right) d\,x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2d)$$

Now, the total internal work of flexure for the beam (as far as bending moments are concerned) is known to be

$$W'' = \int_o^l \frac{M''^2\,d\,x}{2\,E\,I};$$

and hence, by Castigliano's Theorem, just mentioned, we have, for the deflection, $\triangle'$, at the point of application of Q,

$$\triangle' = \frac{d\,W''}{d\,Q};$$

that is,

$$\triangle' = \int_o^l \left[2\,M''\,\frac{d\,M''}{d\,Q}\right]\frac{d\,x}{2\,E\,I}, = \int_o^l \frac{M''}{E\,I}\left(\frac{d\,M''}{d\,Q}\right) d\,x; \ldots\ldots (2e)$$

which is seen to be identical with Equation 2*d*.

It follows, therefore, that the quantity, m, while numerically equal to the bending moment that would be due to a force of unity at the point of application of Q and having the same direction, is simply the derivative of the total bending moment at any section, with respect to Q. As already noted, this derivative is independent of the magnitude of Q (M'' being a linear function of Q), and hence has the same value, when Q becomes zero, as for any other magnitude. It is thus seen that the "Fraenkel Formula" is a particular case of "Castigliano's Theorem."

Mr. Church. While the "Fraenkel Formula" is doubtless the most advantageous for the problems treated in this paper, it may be of interest to call attention to the fact that the "Theorem of Three Moments" (with variable moment of inertia), may be used for the same purpose (if the influence of shear be disregarded), for the reason that in its most general form this theorem relates to any three points in the elastic curve of a bent beam (whether or not there are supports at any of these three points); and that it introduces the deflection of the intervening point below the straight line joining the other two. When the theorem is applied to Problems Nos. 1, 2 and 3, of the paper, the three points chosen would be the two extremities of the beam (over the supports), and the point whose deflection is desired. Under these circumstances, the desired deflection is identical with that which appears in the statement of the theorem, and the end moments are each zero; so that a solution is immediately effected for the deflection. A similar obvious application may be made for Problems Nos. 4 and 5.

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AUTOMATIC MODULES FOR REGULATING THE SPEED OF FILTRATION.

Discussion.*

By JOHN H. GREGORY, Assoc. M. Am. Soc. C. E.

Mr. Gregory.

JOHN H. GREGORY, Assoc. M. Am. Soc. C. E. (by letter).—The author presents a paper on a subject which is of great interest to those who have had occasion to design apparatus for regulating the rate of filtration.

The author states, in the second paragraph:

"Numerous forms of semi-automatic apparatus of this description have been devised, but as, under the law of the survival of the fittest, they appear to be doomed to speedy extinction," etc.

It is presumed that the author intends to classify under "semi-automatic apparatus" all apparatus which requires hand regulation, and if such is the case, the writer differs decidedly from the statement that such apparatus appears to be doomed to speedy extinction.

The author goes on to state that "at all events, for the purpose in view, it has not been considered expedient to include any special mention of them (semi-automatic apparatus) herein." The author's purpose was to describe automatic modules, as is revealed in the title of the paper, but the writer thinks that it would have been expedient to describe some of the forms of semi-automatic apparatus, point out the defects that may exist, and give reasons for not advocating them.

The author, possibly, is not acquainted with recent American practice in this line; but, if so, he could not have failed to note that in two of the largest and most recent plants, which it is hoped will be

*This discussion (of the paper by Charles Anthony, Jr., M. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
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Mr. Gregory. placed under construction in the near future, hand regulation has been adopted. The writer refers to the proposed slow sand filters at Pittsburg, the construction of which, unfortunately, seems to be postponed for some little time, and to the filters at Washington, D. C., contracts for which, according to the latest press reports, have just been awarded. While full details of these proposed plants have not been published, sufficient details have appeared in American engineering periodicals, in the last year or so, to show that hand regulation has been the type adopted. The writer knows of one other plant, which has been built during the last year, in which hand regulation is used. In another large plant which is to be built shortly, on the details of which the writer was asked to advise, the unanimous opinion of all concerned was in favor of hand regulation, and the details for the plant have been thus drawn. It would seem from this that, in the United States, hand regulation or semi-automatic apparatus is not doomed to speedy extinction.

The writer has had considerable experience in the last few years in designing apparatus of both automatic and semi-automatic types, and in watching the operations of both, and it may be of interest to point out some of the advantages and disadvantages of each.

While connected with the construction of the Albany filtration plant, designed and built by Allen Hazen, M. Am. Soc. C. E,, he had the opportunity of watching the daily operation of the filters for several months. The apparatus at Albany, as is well known, consists of an orifice, 4 ins. high and 24 ins. long, in a fixed brass plate, situated in a cross-wall in the regulating chamber. The head on the orifice is maintained at a constant level by opening or closing a valve on the main effluent pipe from the filter. Suitable floats, with scales and markers, indicate the rate of filtration on the filter, corresponding to the head on the orifice. The apparatus was designed so that with a head of 1 ft. on the center of the orifice the rate of filtration would be 3 000 000 galls. per acre per 24 hours, and the orifice was placed so that the loss of head could reach a maximum of 4 ft. while still maintaining the head of 1 ft. on the orifice. The filters were designed to run at a normal rate of 3 000 000 galls. per acre per 24 hours, and no difficulty was experienced in throttling the valve on the effluent pipe so that the head on the orifice would be 1.00 ft., or, at the most, 1.01 ft. The variation in rate corresponding to these two heads is only a fraction of 1%, and is so small that it may be neglected.

After a filter is scraped, and when it is put in service, the loss of head is of course small, only a few hundredths of a foot; this increases gradually from day to day, slowly at first, but quite rapidly toward the last end of the run when the filter is clogged. The readings of the loss of head and rate of filtration are taken every few hours, and, if need be, the effluent valve is opened slightly to bring the rate of fil-

tration back to the normal rate desired, as the rate drops off slightly during the period. This dropping off in rate is only a small amount, but, of course, is greater toward the last of the run; in both cases, however, it is not sufficient to affect the quality of the filtrate. Mr. Gregory.

One possible objection to hand regulation in separate regulating houses may be raised, in that the opportunity is afforded the attendant to be negligent in his duties of regularly visiting the filters, and with little chance of detection. The larger the plant, the greater the objection might be; but the writer does not think that it is of sufficient importance to govern the selection of the type of apparatus to be used, except under certain abnormal conditions. He believes that it is as easy to obtain an attendant at a filter plant who will perform his duties faithfully as it is to obtain a watchman, who, in an entirely different kind of plant, will perform other duties faithfully.

If, now, instead of separate regulating houses, a single central regulating house is used, to which the effluent from each filter is piped, especially if the office is in the same building, the possible objection to hand regulation is removed. This latter is an arrangement which the writer has advocated for several years where the general lay-out of the plant is such as to admit of it.

Hand regulation, whether in single regulating houses or in a central one, is advantageous in one respect, in that it requires periodical attendance at each filter, thereby ensuring that any irregularity will not pass long unobserved. With apparatus of the automatic type it is possible, of course, to lengthen materially the period between observations, in fact, with the apparatus set at a given rate to allow it to run until the loss of head is so great that the filter goes out of service. Under this extreme condition, if anything went wrong it would not be known. On the other hand, with satisfactory automatic apparatus, if for any reason the attendance for a short time is omitted, one can feel reasonably assured that things are going along all right. While hand regulation, from its nature, requires periodic attendance, the writer is decidedly of the opinion that automatic apparatus should receive just as careful attention, if the operation of the plant is to be above criticism.

The author makes a very convenient classification of the various automatic modules, and, as would the writer, mentions the floating weir first, that being the type which would first suggest itself. In one of the figures, the author illustrates an apparatus of this type which he calls the Glenfield Jones, in which the discharge is regulated by varying the depth of submergence of the weir; and in commenting on this he states that:

"This, however, is an imperfect type, as friction causes the weir to be more or less submerged, depending on whether it is floating on rising or falling water, and, furthermore, the adjustment for varying the discharge is cumbersome and inconvenient."

Mr. Gregory. As to whether or not apparatus of this type is imperfect, it would seem to depend almost entirely on the design of the details. If the sliding joint is arranged so that the friction is an appreciable quantity, the apparatus will be more or less imperfect; but experience seems to indicate that the friction at this point can be reduced to such a small amount that it can be neglected. As to whether or not the adjustment for varying the discharge is cumbersome and inconvenient, while it may be so with the apparatus illustrated, it can be said that this also depends entirely on the design of the details. The writer knows that it is possible to construct apparatus of this type so that the adjustment is accomplished in the simplest manner possible, that is, by turning a hand-wheel on an indicator stand.

While considering this subject, it may be of interest to illustrate three sets of apparatus of this type which were designed under the writer's direction for the slow sand filters at Philadelphia. The figures are only drawn in sufficient detail to indicate the general design and operation of the apparatus.

In Fig. 12 is shown the type which was first designed, and which is now in use at the six filters at the Lower Roxborough plant. This consists of a circular copper float, *F*, in the form of a torus, carrying above and secured to it a four-armed cast-iron spider, *Y*, through which is threaded a stem, *S*, at the hub, *A*. On the lower end of the stem, *S*, is carried a smaller four-armed spider, *K*, made of brass, so joined to the stem at *B* that it can turn freely in a horizontal direction, but without any vertical movement on the stem. This spider, *K*, supports a vertical brass pipe, *T*, which, for convenience, may be called the telescopic pipe, the top of which forms a sharp-crested weir, *W*, over which the water flows. This telescopic pipe is enclosed in a cast-iron casing, *C*, the lower end of which connects with the main pipe leading to the filtered-water basin. The telescopic joint, *J*, through which the pipe, *T*, passes, is a brass ring, and is arranged with grooves so that light packing could be inserted if desired. The stem, *S*, is of brass, the lower end only being circular and threaded; above, it is of square brass tubing, and passes up through a circular hole in the floor, which serves to guide the stem. Above the floor is placed an indicator stand with a hand-wheel. The stem passes up through this stand without being connected to it, the hub of the hand-wheel having a square hole through it slightly larger than the stem.

As shown, water is passing over the crest of the weir, thereby giving a certain rate of filtration on the filter. If it is desired to change the rate, this is accomplished by turning the hand-wheel on the indicator stand. By doing so, the stem, *S*, is turned, and, as it is threaded through the spider at *A*, the telescopic pipe, *T*, is raised or lowered with reference to the water level, correspondingly decreasing or

Mr. Gregory.

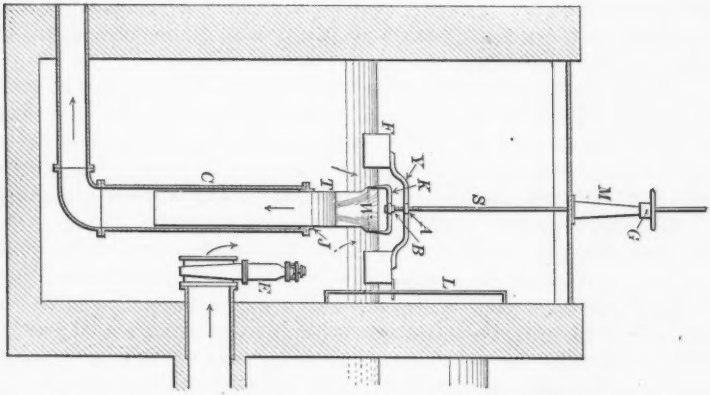


FIG. 12.

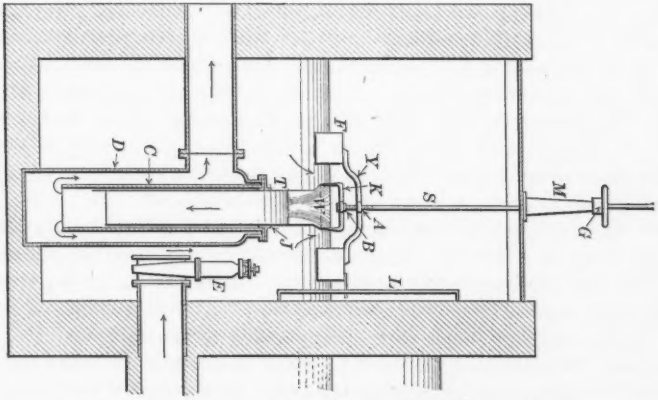


FIG. 13.

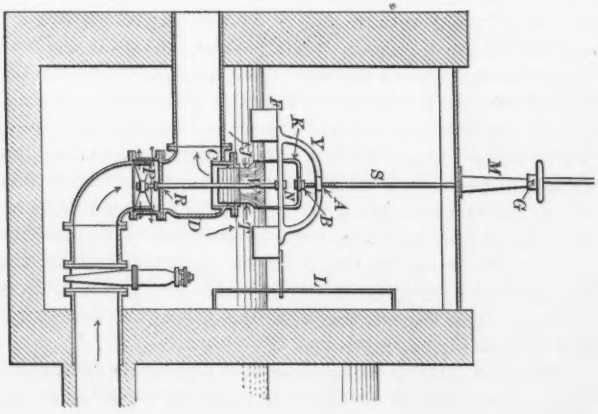


FIG. 14.

Scale of Feet
0 1 2 3 4 5 6

Mr. Gregory. increasing the rate. In order that the float, *F*, shall not turn with the stem, a small projecting piece is fastened to it, moving along the guide, *L*, which is fastened to the wall.

The rate of filtration is indicated by a pointer moving over a small horizontal dial at *G*, directly under the hand-wheel. The movement of this pointer is accomplished by means of a brass collar, with a square hole, fitting around the stem, and forming the worm of a train of gearing. The graduation of the dial is determined from experiment rather than from computation.

The weak point in apparatus of this type is, of course, at the joint, *J*. When it came to designing this joint, three styles were considered, one being that shown, another a thin plate with a hole very slightly larger than the telescopic pipe, and the other a cup leather. The writer rather leaned toward the leather joint or the thin plate, but after discussion it was finally decided to adopt the one shown, with the provision, however, that the design should be such that either of the others could be substituted if it was found desirable. It should be remarked that with either of the types which do not make a tight joint at *J*, there will be a certain amount of leakage, greater, of course, at the first of the run when the head is greater; but, in the writer's opinion, this leakage would be so small, compared with the amount passing over the weir, that it would not be a serious matter. This leakage, however, is to be avoided if possible.

After this apparatus was installed it was found that with the joint as designed it did not operate satisfactorily. The writer understands that the cup leather has now been substituted and is giving very satisfactory results.

In designing both sets of apparatus it was intended to provide access for air under the sheet of water, and it was thought that sufficient opening had been provided at the four points where the spider, *K*, was joined to the pipe. It was expected, however, that there would be some entrained air carried along in the solid column of water passing down through the telescopic pipe, due to the agitation at the surface produced by the falling sheet of water. In either event it was not anticipated that it would amount to much. It seems that such, however, was not the case, and that there has been some little trouble caused by air being sucked in. The writer has not had the opportunity of studying the apparatus for any length of time while in operation, and hence cannot suggest what he would consider the best way of remedying it; but, from his knowledge of all the details, several methods have suggested themselves. The trouble with the air in the water passing out through the apparatus, however, does not affect the satisfactory operation of the filter.

When it came to designing the Upper Roxborough and Belmont plants it was found desirable to raise the elevation of the effluent pipe

leading from the regulating chambers. This resulted in a modification of the design of the regulating apparatus, which modification is shown in Fig. 13. The upper part of the apparatus is the same as that just described. The change in the lower part is indicated clearly in the drawing. The object in providing the internal casing, *C*, was to prevent a possible cramping of the telescopic pipe, *T*, in the joint, *J*, due to the lateral movement of the water as it passed out into the effluent pipe leading from the chamber. This modified type of apparatus was also included in the designs of the Torresdale plant, to be used for all the filters except one, in which was to be installed a still further modified type. Mr. Gregory.

All the apparatus was designed to run for a maximum rate of filtration of 6 000 000 galls. per acre per 24 hours, and with a maximum loss of head on the filter of 5½ ft. It is readily seen, then, that when the filter is first started after scraping, the water passing over the weir falls several feet, causing the agitation mentioned previously. It should also be noted that during the run the telescopic pipe has a vertical movement corresponding to the total loss of head, and a consequent variation in leakage if a tight joint is not used at *J*, as before stated. It was in an attempt to improve both these features that the apparatus illustrated in Fig. 14 was designed.

The indicator stand, the stem, *S*, the joints, *A*, *B* and *J*, and the float, *F*, are the same as described previously. The spider, *K*, is lengthened vertically, but has no connection with the spider, *Y*, except through the stem, *S*, although the drawing might seem to indicate otherwise. The spider, *Y*, is a double one, the upper part being similar to the one described previously, and serving the same purpose; the lower part carries a vertical valve stem at *N*. The telescopic pipe, *T*, is made much shorter, while the outlet casting, *D*, is quite different in form. Below this outlet casting, *D*, there is a solid plate with an opening at *R* for the valve stem, and below the plate there is a balanced piston-valve, placed on the end of the main effluent from the filter. This valve consists of a hollow internal cylinder or piston, *P*, with openings, surrounded by an annular casing, also with openings. The position of the piston, *P*, is controlled by the float, *F*. The method of changing the rate of filtration, as with the other types, is by changing the level of the crest of the weir, *W*, relative to the water level in the chamber.

The operation of the apparatus may be described as follows: When the filter is started, after scraping, the piston, *P*, will be at its lowest position, with its openings opposite those in the annular casing. The water will pass out through the piston-valve into the chamber, rising up around the float and passing over the weir. When the water has reached a sufficient elevation, the float will rise, carrying with it the piston, *P*, and thereby partly closing the openings in the annular

Mr. Gregory. casing. The float will rise to such a position that the water discharged through the piston-valve will be the same as that passing over the weir, in which position the apparatus will be in equilibrium. The difference in head between the water level on the filter and in the chamber, minus the head lost in passing the filter, will be used up in passing through the piston-valve. At the beginning of a run this head will be several feet, but at the last end will be only a small amount. If at any time the rate is changed, the position of the float and piston will be altered slightly to correspond to the new condition of affairs.

It will be seen, then, that with this type of apparatus the water level in the chamber will remain practically constant, varying at the most only a few inches instead of fluctuating several feet, and thereby giving practically a constant leakage at *J*, if a tight joint is not used. The telescopic pipe, *T*, will have a vertical movement of only a few inches, and its length has been reduced to a minimum. A cup-leather joint, preferably, would be used at *R*, to prevent leakage at this point.

The writer wishes to acknowledge his indebtedness to Mr. L. M. Lloyd and Mr. F. C. Dunlap, his assistants, for several valuable suggestions in working out the details of the three types of apparatus just described.

In conclusion, the writer would add to the two requirements which the author points out should be fulfilled by automatic apparatus, a third, namely, that the loss of head caused by the apparatus should be reduced to a minimum. In the Philadelphia designs it was this requirement which was the determining factor in deciding the use of the floating weir in which the submergence of the weir could be varied.

Vol. XXIX. MAY, 1903. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

A SMALL ROCK-FILL DAM.

Discussion.*

By Samuel H. Lea, M. Am. Soc. C. E.

Samuel H. Lea, M. Am. Soc. C. E. (by letter).—The writer is unable to see the advantage in hand-packing the up-stream portion of the rock fill. The author states that the object was to help to make the dam water-tight by offering narrow and broken joints which would retain the matter carried in by leakage. This reason would have considerable weight if the up-stream face of the rock fill had been left exposed and free to receive the full volume of silt and suspended matter contained in the water. As the dam was backed with earth on the up-stream side, the only matter that could be carried into the rock fill would be from the earth fill. This fill is stated to consist almost entirely of clay, an impervious material allowing little or no leakage. Mr. Lea.

The writer thinks the hand-packing of the up-stream face of the rock fill rather a disadvantage, except in the respect that the portion thus packed would naturally be of greater solidity and would consequently afford greater stability to the structure. This effect could have been obtained by building the up-stream portion of the rock fill with a slope of 1¼ to 1 and placing the stone without hand-packing. This proceeding would have required an additional quantity of stone, but the cost of the extra stone would have been more than compensated for by the smaller unit cost of the stone in place and by the decrease in the yardage of the earth fill.

*This discussion (of the paper by H. de B. Parsons, M. Am. Soc. C. E., printed in *Proceedings* for March, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Lea. As constructed, the rock fill and the earth fill meet in a comparatively smooth surface, affording no chance for a bond or connection between the two substances. This surface constitutes, in effect, a plane of weakness, which is likely to become a sliding plane if storm-water or flood-water uses it as a channel or duct. Should this occur, the displacement of parts of the earth filling nearest the rock might follow, and this would cause settlement in the earth fill. If the slope suggested by the writer—1¼ to 1—had been used, and the earth nearest the rock had been well tamped into the interstices between the stones and the irregularities of the surface, a good bond would have been formed between the earth and rock fills and the liability to slip thereby lessened. In addition, the danger of the penetration of storm-water or flood-water would have been minimized.

If preferred to have the up-stream face of the rock fill hand-packed, it would have been better to have finished it in steps. The earth filling next to the stone could have been selected clay carefully tamped. A good bond would thus have been formed. The author does not state whether the cut-off trench was connected with the dam in any manner to prevent seepage over the top of the sheet-piling. To insure water-tightness the trench should have been filled with clay well puddled, and the filling carried up over the face of the rock fill for a foot or more, joining the clay filling next to the rock fill.

In large rock-fill dams, constructed in the West, provision is generally made for water-tightness by special constructions, such as timber facing, steel diaphragms coated with asphalt, or by other methods.

The writer believes that the methods suggested by him will meet all requirements in the case of a small dam such as that under consideration.

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PAPERS AND DISCUSSIONS.

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NOTE ON THE COEFFICIENT OF ELASTICITY OF CONCRETE AND MORTAR BEAMS DURING FLEXURE.

Discussion.*

By W. K. HATT, Assoc. M. Am. Soc. C. E.

Mr. Hatt.

W. K. HATT, Assoc. M. Am. Soc. C. E. (by letter).—The coefficient of elasticity used ordinarily by the designer of steel-concrete beams is that for direct tension or compression. It does not seem that the moduli given by Mr. Falk are of value for this purpose.

Assuming, however, that the results desired by the author are useful, it appears that the details of the method of measuring deflections by means of a lever deflectometer should have been related. If this lever was placed directly under the beam, the amount of compression at the supports must have influenced the character of the curves shown in Fig. 1. Especially, in the case of the shorter beams, is it true that the deflections are probably due to compression at the support, shear of the beam, and bending of the beam. The ratio of height to span of only 1 to 4 in the case of the half beams is too small to yield proper values of the coefficient of elasticity in bending.

The author does not describe the method of calculation used to determine the coefficient of elasticity and the extreme fiber stress quoted in Table No. 1. If these are the result of the application of a formula that is based upon an assumption of a rectilinear relation between stress and strain and of equal moduli in tension and compression, it is the writer's opinion that the results of such computations are of little significance.

*Continued from April, 1903, *Proceedings*. See February, 1903, *Proceedings* for paper on this subject by Myron S. Falk, Jun. Am. Soc. C E.

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PAPERS AND DISCUSSIONS.

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THE PRESERVATION OF MATERIALS OF CONSTRUCTION.

An Informal Discussion.*

By Messrs. James Forgie, William R. Webster, Horace J. Howe, Theodore Belzner and William W. Crehore.

Mr. Forgie.

James Forgie, M. Inst. C. E. (by letter).—Quite recently, and incidentally, the writer mentioned to Mr. Noble that he had a piece of iron, about 200 years old, in the form of a masonry cramp or bonding iron, approximately ⅜ x ¾ x 6½ ins., with the addition of the ends turned down (Fig. 2), and which he thought might be worthy of testing, both physically and chemically.

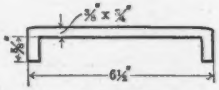


Fig. 2.

Mr. C. L. Harrison has suggested that, in view of the discussion on "The Preservation of Materials of Construction," a note of the history of this piece of iron might be presented, and, probably, in view of the gigantic iron-framed buildings, where the iron is largely inaccessible for painting, it may be of all the more interest to American engineers.

In 1899, while acting for Sir Benjamin Baker and Messrs. Hay and Mott as Chief Assistant Engineer on the City and South London Deep Underground Railways, the writer found this piece of iron within the sandstone masonry of one of four piers forming the pedestals of four triple sets of stone Corinthian columns which were being underpinned to steel girders, in the process of forming a railroad depot in the crypt or vaults of St. Mary Woolnoth Church, at the junction of Lombard and King William Streets, facing the Bank of England, in London, England.

* Continued from the *Proceedings* for March, 1903.

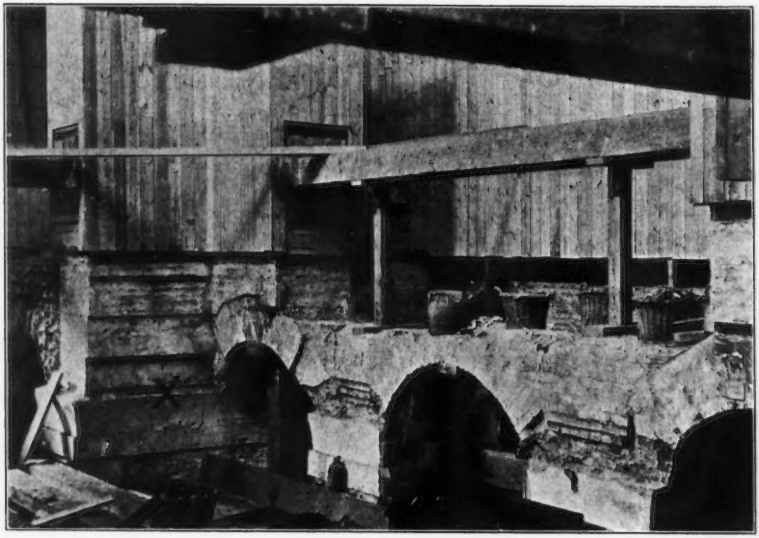


FIG. 1.—PARTIALLY DEMOLISHED CRYPT OF ST. MARY WOOLNOTH CHURCH. THE CROSS INDICATES THE PLACE FROM WHICH THE IRON CRAMP WAS TAKEN.

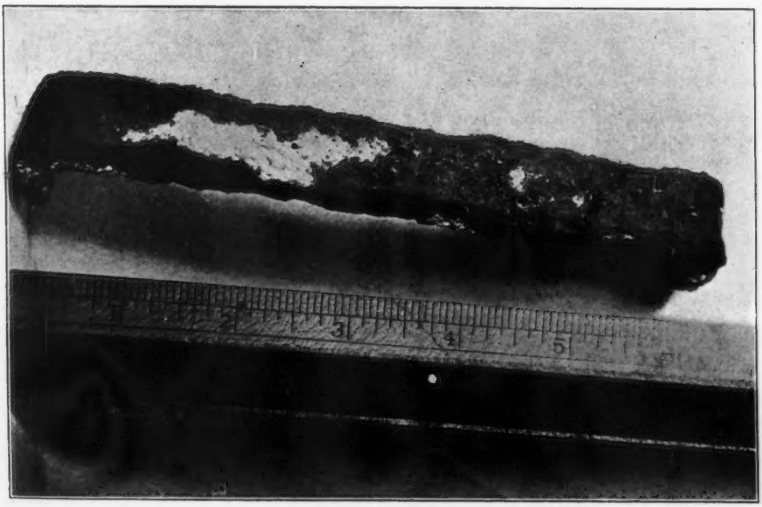


FIG. 2.—IRON CRAMP TAKEN FROM MASONRY IN CRYPT OF ST. MARY WOOLNOTH CHURCH, LONDON, ENGLAND.

From this pier also radiated the vaulting or arch groining forming the floor of the church and the roof of the crypt, where, also, several human bodies were found encased in complete lead-shell coffins embedded in the foundations. Mr. Forgie.

This church was built on the site of a church destroyed previously by the great fire of London in 1666, and was designed by Nicholas Hawksmoor, a pupil, and eventually a contemporary, of Sir Christopher Wren.

The iron cramp or bond was wholly embedded in a horizontal sandstone masonry joint made of lime (a hydraulic and not a pure lime).

It may be observed that practically no oxidation can be discerned by the microscope. Attention is also drawn to the pieces of lime still clinging to the iron.

It may be that the lime has acted as a preservative, and, *a propos* of this, the writer may be permitted to observe that in 1895 a piece, about 12 ins. square, of the cast-iron shell of the Tower Subway under the Thames, built in 1869–70, was cut out for the inspection of the Arbitrator in the City of London *versus* the Subway Company. The writer saw this piece immediately after it was cut out, and, on removing the shell of lias (hydraulic) lime grout from the iron, the thin coating of coal tar, which still remained on the iron, smelt perfectly fresh, and the iron was in perfect condition. Within the past six or seven years the writer has removed several hundred feet of other cast-iron tunnels in the process of enlarging the Subway. These had been in place from ten to twelve years, and the iron was also found to be in a perfect state of preservation. The soil in which these tunnels are built is a stiff blue moist clay.

On account of the strong belief in hydraulic lime and Portland cement as a preservative of iron, all the 400 to 500 tons of steel columns and girders which now carry the afore-mentioned church, over the railway depot, were covered with expanded metal and then wholly encased in neat Portland cement.

Fig. 1, Plate XLII, is a photograph, of the partially demolished vaulting of the church, on which the place from which the iron cramp was taken is indicated by a cross. Fig. 2, Plate XLII, is a photograph of the cramp.

William R. Webster, M. Am. Soc. C. E. (by letter).—The small iron cramp referred to by Mr. Forgie, which was subsequently sent to the writer for test, seems to have been originally $\frac{3}{4} \times \frac{3}{8}$ in., one end thickened in bending and the other end considerably wasted away. Mr. Webster.

Before testing the cramp the ends were sawn off, leaving them in their original condition. The material was very hard in spots, and three hack-saws were dulled in cutting off the ends. The body of the cramp was cleaned of all scale and mortar by light blows of a hammer. It was rusted badly in some places under the adhering mortar. In order to grip it in the testing machine it had to be reduced in thick-

Mr. Webster. ness, and on pulling developed a bad seam, otherwise the ultimate strength would, no doubt, have been somewhat higher. The following are the results obtained:

Area.	Ultimate strength.	Percentage of elongation in 2 ins.	Percentage of reduction.
0.104 in.....	51 226 lbs.	18.00	35.3

Analysis.—Carbon, 0.008%; sulphur, 0.027%; phosphorus, 0.060 per cent.

The writer is indebted to Mr. R. Job, Chemist of the Philadelphia and Reading Railroad Company, for the chemical determinations.

Mr. Belzner. THEODORE BELZNER, Jun. Am. Soc. C. E. (by letter).—Regarding the steel beams taken out of the sidewalk vault, mentioned by Mr. William Barclay Parsons,* the writer would like to know whether, from Mr. Parsons' observations, these beams had received a shop coat of oil.

Steel, embedded in concrete, such as grillage beams, etc., should be cleaned thoroughly. The writer does not think it necessary to have them painted; but, of course, this does not apply to steel which is partially embedded in concrete, such as the side columns, roof beams and girders having exposed surfaces, now being used in the construction of the New York Rapid Transit Subway. Steel which is partially embedded in concrete should be cleaned thoroughly, either by the sand-blast process or by brush and scraper, and then given a good priming coat of red lead, to be followed by a protective coat of some standard carbon paint.

Mr. Howe. HORACE J. HOWE, M. Am. Soc. C. E. (by letter).—Reference might profitably be made, it seems to the writer, to the remains of the habitations of the Ancient Lake Dwellers of Switzerland, as furnishing the best authentic instances of the preservation of wood and other substances under the most favorable conditions, from pre-historic times (in fact, from the New Stone and Copper Ages) up to the present time.

The building up of the habits and customs of that period, by means of somewhat advanced Sherlock Holmes methods, is very interesting, but hardly calls for more than a mention here.

In the winter of 1853–54, the waters of Lake Zurich fell to a remarkably low level, thereby revealing certain piles in the bottom, at no great distance off shore. These piles proved to be from 15 to 30 ft. in length and from 3 to 9 ins. in diameter. They were in rows, sometimes parallel to the shore, sometimes at right angles to it, and

* *Proceedings*, Am. Soc. C. E., for March, 1903, p. 307.

were either firmly embedded in the mud or supported by heaps of stones at the base. Sometimes they were driven through boards which rested on the bottom. Mr. Howe.

The piles were braced together by means of transverse beams with wooden-pin connections, and planked over so as to form a platform on which the huts were built.

There was also a draw-bridge connection with the shore.

Few piles now project more than 2 ft. from the bottom. They are saturated so thoroughly with water that they are quite soft. Some of them appear like needles, which elsewhere have disappeared and left only a black disc. This is true, however, principally of the oldest, those of the Neolithic Age.

The point which entered into the mud still bears the marks of the fire and of the stone hatchets, or later on, of the metal hatchets. The manner of driving to so great a depth into the ground is difficult to imagine.

As to the various objects which give the key to the doings of this people, Sir John Lubbock says :*

"Lying among the piles are fragments of bone, horn, pottery and sometimes objects of bronze. Most of them are imbedded in the mud or hidden under the stones, but others lie on the bottom, yet uninjured; so that when, for the first time, I saw them through the transparent water, a momentary feeling of doubt as to their age rose in my mind. * * * The upper parts of the objects also, which are bathed by the water, are generally covered by a layer of carbonate of lime, while the lower part, which has sunk into the mud, is quite unaltered."

In many other Swiss lakes, habitations are indicated in like manner, and it is understood that the Swiss archæologists have made the most of a golden opportunity. The Antiquarian Society of Zurich—Keller and others—was one of the first to do so; and it is quite possible that an official correspondence with that society would be productive of results as to the present status of the entire subject.

William W. Crehore, M. Am. Soc. C. E. (by letter).—In the previous discussion of this subject one point concerning the protection of metals by paint seems to have been entirely lost sight of. When the first coat of paint is applied to the bare metal, the action is somewhat analogous to that which accompanies the application of the priming coat to a piece of soft pine; the oil soaks into the "pores" of the metal and carries the pigment with it. In cast iron the action is discernible to the naked eye, but it takes place also in steel, although to a less extent, on account of the greater density and, consequently, the less porosity of the latter. Mr. Crehore.

Obviously, the oil in a paint is the conveyer, or the medium by which the pigment is brought in contact with the metal. The oil is,

* "Pre-Historic Times."

Mr. Crehore. also, to a certain extent, a protector of the metal when it is itself protected by the pigment. Pure oil, by itself, unmixed with a pigment, will protect the metal as long as it lasts, but it very soon evaporates and is gone. In the mixture the oil which is outside, next the air, soon evaporates and leaves the pigment, while the oil which is inside, next the metal, remains there permanently because of the protection afforded by the outside pigment. In order to protect the coating next the metal more thoroughly, therefore, a second coat of paint should be applied as soon as possible after the first one is dry.

In view of this combined action of the oil and the pigment it follows that the further the pigment can be injected or carried into the pores of the metal, the better is the bond between the paint and the metal; and if the pigment itself is a good protector its efficiency is certainly increased rather than diminished by being well bonded. Owing to the great density of steel or iron, this action is very slight, in comparision with the absorptive power of wood, and its amount depends upon the fineness of the pigment, as well as upon the density of the metal. This is one reason why paints differ in efficiency as protectors of metal. The more finely ground pigment makes the better metal paint, other things being equal, and such a pigment is conveyed better by a thin oil than by any other. Then, too, the quantity of oil in the mixture is an important point, as well as the degree of completeness with which the oil and the pigment have been mixed together. The requirements, therefore, for a good metal paint are somewhat analogous to those for a good concrete. As, for the latter, there should be just enough cement to fill the interstices between and to cover completely each particle of sand, and just enough of the mixture to fill the interstices in the stone; so, for the former, the pigment should be ground fine enough to enter the pores of the metal, the oil should be of correct quantity, so that it is thoroughly filled or loaded with the pigment, and thin enough so that it will carry the pigment into the pores of the metal. It seems, then, that to produce the ideal metal paint requires: (1) that the pigment should be a good protector, (2) that the pigment should be very finely ground, (3) that the oil should be pure and very thin, (4) that there should be just enough and not too much oil in the mixture, (5) that the two should be completely mixed together.

Furthermore, to obtain the best results, such a paint must be applied next the bare metal itself, without any intermediate coating of oil or scales of rust, either of which obstructions will prevent the pigment from reaching the pores of the metal. The writer contends that the metal should be absolutely bright and clean before being painted. The fact, referred to by Mr. Seaman, that the first coat of paint will adhere better to metal with a dull surface than to metal with a bright surface is because the dull surface possesses the greater

porosity of the two and consequently affords a better opportunity for bonding the paint. Experience, however, shows that to check rust which has once begun is impossible, but that it keeps on increasing even though covered with a good paint. In view of this fact it is best to have the metal cleaned by sand-blast, before being painted, in order to insure the best results, with any paint. Mr. Crehore.

The action of the cement in a concrete covering for metal work is practically the same as that of a good paint. The cement will adhere better to the metal if there be nothing between it and the bare surface of the metal; and the concrete forms fully as good protection, under ordinary conditions, as would a good paint. If, however, the metal is located where there is occasional moisture, ordinary concrete is not a sufficient protection, and in such a case the metal should be painted before being set. On the other hand, if the concrete and the steel are expected to act together to resist stress in combination, a coat of paint prevents bonding between the metal and the concrete, and then it should not be used.

That we have not sufficient data to establish indisputably the superiority of those paints which approach more nearly than others to the conditions above mentioned, is chiefly because this subject has never been handled scientifically. Most of our observations are general, or are made under different conditions, and nearly all the available data have been compiled by men who were biased or prejudiced by a personal interest in one or another party to the competition. Comparisons to determine the relative efficiencies of different paints should be made by an absolutely disinterested commission, and under sufficiently varied conditions to establish superiority in one or another of the points now in dispute; such points, for instance, as whether the pigment or the oil is the more important element in the durability and efficiency of paint; what substances make good pigments and what substances are absolutely without merit as pigments; what the comparative effect would be of deleterious chemical fumes on the pigments of different paints; whether a given paint is less efficient when put on with a spray than when rubbed in with a brush, etc., etc. The report of such a commission need not favor any one paint exclusively, but it should define thoroughly the principles on which the composition of a good paint is based, and it could divide all who entered the competition into classes or groups graded according to relative merit in certain important features of the examination.

The writer believes that several of the manufacturers of paint would not only enter their products for comparative examination and exhaustive tests, but also would be glad to share the necessary expense of such work, provided they were assured of the absolute fairness and impartiality of the tribunal and its ability to handle the subject in a spirit of practical and scientific research. A Special

Mr. Crehore. Committee appointed by this Society ought to carry the weight necessary to make its results of great value, and to induce those manufacturers who have any confidence in their products to enter the race voluntarily. Most engineers are in great need of some authoritative information on this subject, aside from the variety of conflicting data and theories gratuitously furnished by paint manufacturers, and cannot afford either the time or expense to investigate it individually.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ROBERT BLUM OLNEY,* Assoc. M. Am. Soc. C. E.

DIED MARCH 4TH, 1903.

Robert Blum Olney was born on September 20th, 1870, at Charleston, South Carolina. He was the son of Clarence C. and Louisa C. Olney, of Charleston.

From January to August, 1888, he was employed in the office of the Chief Engineer for the Savannah, Florida and Western Railroad (Plant System), and from September, 1888, to June, 1892, he attended Lehigh University, from which he was graduated as a Civil Engineer in June, 1892. At college he was painstaking, and always reliable and trustworthy in his work, and his scholarship was excellent. Professor Merriman states: "His thesis was entitled, 'Plans and Specifications for a Locomotive Round House,' I find the drawings made with great neatness and the subject well treated throughout."

After graduation he was engaged on the Ohio Extension of the Norfolk and Western Railroad, in work varying from reconnaissance to final estimate, locating, re-tracing and revising lines, construction and track laying. In 1893 he was employed making surveys in the Powhattan mines of the Pocahontas coal field. From January, 1894, to January, 1898, he held the position of Assistant City Engineer of Charleston, South Carolina. His work consisted of general municipal engineering and public improvements, pavements, drainage, etc., and the reconstruction of the sea wall at the Battery. He was also Principal Assistant Engineer on the construction of the separate system of sewers—the sewage being lifted by Shone ejectors. From May, 1895, to May 31st, 1901, he was Engineer and Superintendent in charge of the sewers, power-house and other details connected with the sewer plant.

In June, 1901, by leave of the Mayor of Charleston, at the request of The American Pipe Manufacturing Company, he resigned his position in charge of the Charleston sewerage works and accepted a position with the latter company. In that capacity, he made topographic and hydrographic surveys for the location of a projected new water supply on Goose Creek at Charleston, South Carolina. During the summer he was engaged on the plans for the new Charleston Water-Works, and in the fall of 1901 he made extensive topographic sur-

* Memoir prepared by J. W. Ledoux, M. Am. Soc. C. E.

veys in Westchester County, New York, connected with water-works systems controlled by The American Pipe Manufacturing Company. In the spring of 1902 he was placed in charge of construction of the separate system of sewerage and the disposal plant for Burlington, New Jersey, the contractors being The National Gas and Construction Company, allied to the American Pipe Manufacturing Company, the sub-contractor being George Pfeiffer, Jr., of Camden, New Jersey.

After the completion of this work he was placed in charge of the construction of Charleston's new water supply from Goose Creek, but, on account of his failing health, remained there but a short time. He then left for the Southwest, intending to locate in a favorable climate in New Mexico or Arizona, but stopped at San Antonio, Texas, where he died on March 4th, 1903. It is stated that he was walking on the streets, apparently in fair health, on the day of his death. His remains were brought from San Antonio to Charleston, South Carolina, his home, and placed in the family plot in the beautiful Magnolia Cemetery.

Mr. Olney was especially capable in his professional work. He was a man of high integrity, and had the respect of all who knew him. The first intimation of his failing health occurred in the winter of 1901–1902 when a New York physician, whom he consulted in reference to some slight ailment, told him that he had symptoms of tuberculosis. This appeared to prey on his mind, although, even up to the last, his health gave no evidence of breaking down.

Mr. Olney was elected a Junior of the American Society of Civil Engineers on January 3d, 1895; and an Associate Member on September 5th, 1900.

WATSON WELLMAN RICH,* M. Am. Soc. C. E.

DIED JANUARY 12TH, 1903.

Watson Wellman Rich was born at Dayton, New York, on March 9th, 1841.

During the past generation he was the best known civil engineer in the Northwest. He spent the major portion of his professional life in the country between the Great Lakes and the Dakota Plains, of which the twin cities of St. Paul and Minneapolis form the commercial center. He was prominent during the three most teeming decades of the marvelous growth and development of this Northwest, through his connection with three of its railroads. He had direct and responsible charge of the construction of some two thousand miles of railroad over that portion of our country.

* Memoir prepared by Samuel B. Fisher, Esq.

Going to the northwest portion of Wisconsin shortly after the Civil War, from which he was discharged as Captain of Volunteers (having refused the command of a colored regiment because he deemed it inconsistent with the high sense of honor held in choice army circles to enter that branch of the service), with previous liberal education, after having spent about two years in the service of various railroads and of the United States Engineer Department as Assistant Engineer, he became identified with the Wisconsin Central Railroad in July, 1870. During the next eight years he was busily engaged in constructing and operating this railroad, through the then almost unbroken forests, over the deep ravines and steep slopes of that difficult country, the south water-shed of Lake Superior, and often in half conflict with its then rough inhabitants.

From 1879 to 1883 he was Chief Engineer of the Minneapolis and St. Louis Railway, building five or six hundred miles of road in Minnesota and Iowa.

All his life he was consulted about, and frequently examined and reported on, enterprises. In this respect he occupied the highest position in the Northwest.

From 1883 to 1890 he was building the principal monument of his career in the construction of the Soo Line, extending from Minneapolis eastward, entirely across the timbered States of Wisconsin and Michigan to Sault Ste. Marie, and westward almost as far as the Dakota Plains. After building the Soo Line his health was not very good, for a couple of years, although he did a considerable amount of miscellaneous work. In 1892 he resumed construction on the Soo Line, putting through its Northwest extension to the International Boundary.

Mr. Rich was most expert and proficient in the use of wood in structures, especially in bridges. His designs and plans for Howe trusses were perhaps the best that have ever been used.

In 1897, ripe in age, rich in engineering experience, strong in character, he went to China. He went first with ex-Senator Washburn to examine the route of the proposed Hankow Railroad for the Brice syndicate. Arriving in China, the Government would not even let him look at it. After some time, however, the Government called for him and delegated him to examine the line, not for the syndicate, but for the Government. On this trip he was accompanied by about a regiment of men, proclamations were sent in advance, calls were made on the Viceroys, etc. There was great difficulty in infusing into the lethargic heels of this superfluous multitude an acceleration of movement proportional to a reconnoissance of six hundred miles of line within a specified time. Early in the progress of this reconnoissance he gave the leader and officer in charge of these auxiliary forces a very practical object lesson, as shown by the following incident related by himself: Proclamations had been sent ahead to hold a feast at a certain

important town, which would have required going into camp about 2 P. M. Mr. Rich, deeming this incompatible with finishing the reconnoissance within the time agreed on with the Government, pushed on with his work, going into camp miles in advance. As the convoy had orders to let no harm befall him, they feared the consequences of disobedience, and came straggling into camp at all hours during the night. There was no further serious difficulty about delays, and this reconnoissance of six hundred miles, on the route which will in all probability be the principal trunk line of China, was completed on time. After having his report translated into Chinese he returned to America, only to go back again in a few months as Consulting Engineer for the Chinese Government, his field being the southern part of the great Chinese Empire. He soon buckled into work, and was engaged in building a coal road a thousand miles in the interior, with the use of Chinese labor and facilities, among which was making embankments with material carried in baskets on the backs of natives, when the Boxer uprising stopped the work.

Actual operations began again soon after the Boxers were suppressed, Mr. Rich's engineers being among the first to return to work. Although he did not again go to the far interior, because His Excellency Sheng required his presence and services in Shanghai, the interior coal road is nearing completion, having been continued in charge of S. L. McCalla, immediately under Mr. Rich's directions.

Since July, 1902, Mr. Rich was a moving spirit in that American enterprise, the Hankow-Canton Railway. In December, 1902, he was appointed Chief Engineer of Construction, of that company. Engrossed in these large affairs, he spent his vital energies in the midst of the novel problems connected with it, and although sustained to the last by his strong will, he died on January 13th, 1903, in Shanghai, which was then his home.

During his intercourse with the ruling and merchant classes of the Chinese he formed a very great admiration for the integrity and other sterling qualities shown in their character, as well as a distrust of the tricky Japanese. In a marked degree, the Chinese gentlemen who knew him confided in him and expressed profound sorrow at his leaving this sphere of existence. Had he lived and remained in the Orient he would have been a strong force in remoulding, or at least modifying, the Chinese character, and conforming its enterprises, to as great an extent as that would have been possible, to lines of modern thought and action.

He was a most masterful man. "His backbone—as he himself expressed it one day—came up into his hat." His friends all know that his heart was bigger than his backbone. He was every inch a gentleman. Like all strong characters, he was forceful in his dislikes and in his few enmities, as well as in his friendships. With his ever

welling-up sense of humor and his genial disposition, he was the most delightful of companions.

Connected all his life with projects for the development of the country, in which large fortunes were made, he never tried to reap personal enrichment from them, but devoted all his time and energy to the interests of his employers. He died a man of small financial means, but rich in good will toward his fellows. He was never known to be envious, but always expressed the most unfeigned satisfaction at the success of his friends. His assistants and subordinates who were brought into close contact with his personality imbibed and ever after maintained feelings of trust and loyalty toward him. His good disposition toward others was contagious. All over the country are men, formerly associated with him, who bear in their hearts the salt of good intentions, infused into them from his ingenuous nature. Dominating all his other qualities, was a regal and ever-present sense of honor.

He was first a well-rounded man, in possession of all his faculties, and afterward a civil engineer. He might have followed almost any other avocation successfully had he devoted his capacity to it. While his work in America was, in a sense, completed, his departure leaves a void in the circles of his friends and engineering associates which can never be filled. It may be truthfully said of him, as it was said of one of old: "Know ye not that there is a prince and a great man fallen this day in Israel."

Mr. Rich was elected a Member of the American Society of Civil Engineers on September 5th, 1883.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 6.

AUGUST, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1903.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 533 Columbus.
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INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

June 3d, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 99 members and 15 guests.

The minutes of the meetings of May 6th and 20th, 1903, were approved as printed in *Proceedings* for May, 1903.

A paper entitled "A New Safety Explosive," by Richard T. Dana, Assoc. M. Am. Soc. C. E., was presented by the author. The subject was discussed by A. McL. Parker, M. Am. Soc. C. E., and the author.

John F. Jackson, Assoc. M. Am. Soc. C. E., described informally the construction of some steel-faced dams recently built in the West.

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Ballots for membership were canvassed, and the following candidates elected:

As Members.

Frank Hooker Alfred, Detroit, Mich.
Willard Lewis Bowker, Portsmouth, N. H.
Edward Du Bois Brown, New York City.
Charles Walter Bryan, New York City.
George Calbraith Clarke, Pittsburg, Pa.
Lewis Augustus Dunham, Kansas City, Mo.
John Meiggs Ewen, Chicago, Ill.
Stetson George Hindes, San Francisco, Cal.
Frank Clifton Kimball, Knoxville, Tenn.
Charles List, San Francisco, Cal.
Wilfred Gillette McConnel, Guantanamo, Cuba.
Edward Furber Miller, Newton Center, Mass.
Henry Hobart Porter, Jr., New York City.
George Rockwell Putnam, Manila, Philippine Islands.
Robert Ridgway, New York City.
Jesse Supplee, Erie, Pa.
Ingvart Teilman, Fresno, Cal.
Thomas William Townsend Tuckey, Tangku, North China.

As Associate Members.

Dorsey Ash, Salt Lake City, Utah.
Shirley Baker, San Francisco, Cal.
George Heckman Burgess, Pittsburg, Pa.
Richard George Doerfling, San Francisco, Cal.
John Turney Fetherston, New Brighton, N. Y.
William Hayden Ford, Philadelphia, Pa.
Charles Newton Green, New York City.
Loren Edward Hunt, Berkeley, Cal.
Arthur Price Law, Bridgeport, Conn.
Thomas R Lawson, Troy, N. Y.
George Stevens Leavenworth, Fairmont, W. Va.
John Brown Lindsey, Jr., Talladega, Ala.
George Kerr Little, Tuscaloosa, Ala.
John Grant MacGregor, Louisville, Ky.
Charles Ephraim McCoy, Lowsville, W. Va.
Castle Prentice Moss, New Westminster, B. C., Canada.
Colone Will Jackson Neville, Chicago, Ill.
George Volney Rhines, Toledo, Ohio.
Felix Charles Stehle, Wissahickon, Pa.
Thomas Corwin Strawn, Hoboken, N. J.

ROBERT SWAN SUMNER, Alamogordo, N. Mex.
ARTHUR WARREN TIDD, New York City.
EMANUEL LOUIS VERVEER, New York City.
IRVINE WATSON, Wheeling, W. Va.

The Secretary announced the election of the following candidates by the Board of Direction on June 2d, 1903:

As Associate.

JOHN MACGREGOR, Baltimore, Md.

As Juniors.

WILLIAM BROKAW BAMFORD, Trenton, N. J.
MAX LEE CUNNINGHAM, Shawnee, Okla.
FREDERICK FISCHER PILLET, Mobile, Ala.
JACOB SCHMITT, Brooklyn, N. Y.
JESSE RUSSELL TAFT, Albany, N. Y.

The Secretary announced the following deaths:

BENJAMIN FRANKLIN JONES, elected Fellow June 1st, 1870; died May 19th, 1903.

HENRY GRANT MORSE, elected Member April 7th, 1880; died June 2d, 1903.

Adjourned.

THIRTY-FIFTH ANNUAL CONVENTION, HELD AT ASHEVILLE, N. C., JUNE 9th, 10th, 11th and 12th, 1903.

Opening Session, Tuesday, June 9th, 1903.—The meeting was called to order at 2.30 P. M., by J. L. Ludlow, M. Am. Soc. C. E., Chairman of the Local Committee.

The Chairman introduced General Theodore F. Davidson, who, in a brief speech, welcomed the Society to Asheville and the State of North Carolina.*

The President, Alfred Noble, M. Am. Soc. C. E., after replying to the address of welcome, took the chair and opened the business meeting.

BUSINESS MEETING.

President Alfred Noble in the chair; Chas. Warren Hunt, Secretary.

The Secretary stated that, as it had been practically understood at previous business meetings that the Annual Convention of 1904 should be held at St. Louis during the Louisiana Purchase Exposition, the customary ballot, asking members to state their preferences as to the place of holding the Convention, had not been sent out.

In reference to holding the next Convention at St. Louis, the Secretary read letters of invitation from Messrs. D. R. Francis, President, Louisiana Purchase Exposition; C. P. Walbridge, President, Business Men's League; Rolla Wells, Mayor of St. Louis; and J. A. Ockerson, M. Am. Soc. C. E.†

On motion, duly seconded, the matter was referred to the Board of Direction with power.

The Secretary read the proposed amendment to the Constitution.‡

It was moved by J. J. R. Croes, Past-President, Am. Soc. C. E., that a third clause be added to Section 1 of Article III, as follows:

"All members other than Honorary Members and Juniors shall be admitted to the Society only by vote of the Corporate Members as hereinafter specified."

The motion, being duly seconded, was carried.

Mr. Croes moved that the second paragraph of Section 3, Article III, be amended so as to read:

"The Board shall have the power to elect persons to the grade of Junior, and to transfer persons from any grade except that of Junior to a higher grade of membership, and shall notify the membership of its action."

The motion, being duly seconded, was carried.

The Secretary presented a communication from James Burden,§ Assoc. M. Am. Soc. C. E., relative to the age at which Juniors shall

* See page 206.
† For copies of these letters see pages 210-211.
‡ See page 211.
§ See page 217.

cease to be connected with the Society; and, at Mr. Burden's request, offered as an amendment that the age be changed from thirty to thirty-five years, which was seconded.

As a further amendment, Henry B. Seaman moved that the age be fixed at thirty-two, which amendment was accepted by the Secretary, acting for Mr. Burden.

After discussion, the motion, being put, was carried.

The Secretary presented a letter from Samuel Whinery,* M. Am. Soc. C. E., relating to the proposed amendment to the Constitution, and it was moved and seconded that the following paragraph be placed at the end of Section 4 of Article III:

"A rejected applicant may renew his application for membership at any time after the expiration of one year from the date of the ballot rejecting his previous application."

After discussion, the motion, being put, was carried. The President then announced that the proposed amendment as amended would be sent out for letter-ballot in accordance with the Constitution.

The proposed amendment, as amended, is as follows:

Amend the Constitution by striking out Sections 6, 7 and 8 of Article II, and the whole of Article III, and substituting therefor the following:

ARTICLE II.—MEMBERSHIP.

* * * * * * * *

6.—A Junior shall not be less than eighteen years of age, and his connection with the Society shall cease when he becomes thirty-two years of age, unless he be previously transferred to another grade. He shall have had active practice in some branch of engineering for at least two years, or he shall have graduated from a school of engineering of recognized standing. Persons who are in the Junior class at the time of the adoption of this Constitution shall not have their status changed by the provisions of this section.

7.—Honorary Members shall be chosen only from persons of acknowledged eminence in some branch of engineering or the sciences related thereto. There shall not be more than twenty at any one time.

8.—Fellows shall be contributors to the permanent funds of the Society, though they may not be eligible for admission as Corporate Members.

ARTICLE III.—ADMISSIONS AND EXPULSIONS.

1.—Honorary Members shall be proposed by at least ten members, and shall be elected only by a unanimous vote of the Board

* See page 219.

of Direction. A Past-President, or a member of the Board of Direction proposed for Honorary Membership, shall not be required to vote either for or against his own admission.

A person elected an Honorary Member shall be promptly notified thereof by letter. The election shall be cancelled if an acceptance is not received within six months after the mailing of such notice.

All members other than Honorary Members and Juniors shall be admitted to the Society only by vote of the Corporate Members, as hereinafter specified.

2.—An application for admission to the Society or for transfer from one grade to another shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected. The applicant shall furnish the names of at least five Corporate Members to whom he is personally known. Each of these shall be requested by the Secretary to address a letter to the Board of Direction, on a form prescribed by said Board, stating the extent of the writer's personal knowledge of the applicant and of his professional work. If at least five of the Corporate Members named as references do not furnish the requisite endorsement, the Secretary shall call upon the applicant for additional names, and not until written communications shall have been received from at least five Corporate Members shall the application be considered by the Board.

Applications of engineers not resident in North America, and who may be so situated as not to be personally known to five Corporate Members, may be recommended for ballot by five members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

3.—At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for admission or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on application for admission may direct a ballot.

The Board shall have the power to elect persons to the grade of Junior, and to transfer persons from any grade except that of Junior to a higher grade of membership, and shall notify the membership of its action.

4.—The ballots shall be letter-ballots, in a form to be prescribed by the Board of Direction. They shall be mailed to each Corporate Member whose address is known, and shall state the date on which the ballot is to be canvassed, which shall be not less than twenty days after the issue of the ballot. Twenty or more negative votes shall exclude from election. In case of exclusion, no notice thereof shall be entered on the minutes, but the candidate shall be notified.

A rejected applicant may renew his application for membership at any time after the expiration of one year from the date of the ballot rejecting his previous application.

5.—All elected candidates shall be duly notified and shall subscribe to the Constitution and Rules of the Society. Forms for these purposes shall be prescribed by the Board of Direction. If these provisions are not complied with within six months from the notification of election, such election shall be considered void, unless for special reason the time shall be extended by the Board of Direction.

Membership of any person shall date from the day of his election.

6.—Upon the written request of ten or more Corporate Members, that for cause therein set forth a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He may, if he so desires, present a written defence which shall be considered at a meeting of the Board of Direction, of which he shall receive due notice. Not less than two months after such meeting, the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a defence made which is satisfactory to the Board, it shall then notify the person that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Corporate Members by letter-ballot in a form to be prescribed by the Board of Direction. The ballot shall be accompanied by a statement of the charges, and of the action of the Board thereon, with such information as it deems proper, and also the statement of the person making the appeal. The ballot shall be canvassed by the Board not less than twenty days after its issue. A majority of the ballots cast will be required to sustain the action of the Board. The Board will notify the person and the Corporate Members of the result of the ballot. In case no appeal be made, the Board of Direction will expel

the person, and notify him and the Corporate Members of its action.

7.—A member of any grade in the Society may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Direction; when, if all his dues have been paid, his resignation shall be accepted.

8.—All persons elected and duly qualified, whose address on the records of the Society is within fifty miles of the Post Office in the City of New York, shall be deemed Resident; and those whose address is beyond that limit shall be deemed Non-Resident.

The classification of each person for the fiscal year as Resident or Non-Resident, shall be determined by the Records of the Society as they may appear on January 1st of that year.

The Secretary presented a brief outline of the inception and history of the proposed co-operation of the Society with other National Societies and the Engineers' Club of New York in the erection of an Engineering Building; and also read the resolutions framed by the Board of Direction for presentation to the Society at the Convention.*

G. W. Catt, M. Am. Soc. C. E., moved the adoption of the resolutions. The motion was seconded. The subject was then discussed.

At 5.50 P. M., adjourned to Wednesday, June 10th, 1903, at 9 A. M.

BUSINESS MEETING—(*Continued.*)

The meeting was called to order at 9.45 A. M., President Alfred Noble in the chair; Chas. Warren Hunt, Secretary.

The discussion on a proposed Joint Engineering Building was resumed.

The following motion, offered by H. S. Haines, M. Am. Soc. C. E., was seconded by Charles Hansel, M. Am. Soc. C. E.

"It is the sense of this meeting that the letter-ballot called for in the resolutions should be presented to the Society with the usual sixty days' notice and opportunity for discussion in business meeting."

After discussion, George S. Davison, M. Am. Soc. C. E., moved in amendment that the words "at the next Annual Meeting" be substituted for the words "in business meeting."

This amendment, being duly seconded, was carried.

B. M. Harrod, Past-President, Am. Soc. C. E., moved that the resolutions offered by the Board of Direction be amended as follows: Add to the third resolution the following:

"And also to make such investigations and hold such conferences as may bear upon the advisability of the acceptance of Mr. Carnegie's proposition by this Society."

* See page 226.

Also insert, in the fifth resolution, after the words "can be obtained," the following words, "and that the acceptance of the proposition is otherwise practicable."

The motion, being duly seconded, was carried.

The resolutions as amended and adopted are as follows:

"*Whereas*, The resolutions submitted by the Joint Conference Committee in the matter of the Proposed Union Engineering Building are not in suitable form, in the opinion of the Board of Direction of the American Society of Civil Engineers, to be submitted to the Society:

"*Resolved*, That it is the sense of this Board that the proposition, when submitted to the Society, should make definite provision for the accommodations necessary for the present and future needs of the several organizations, and that the proportion of the total expense to be borne by each of the organizations concerned should be definitely stated, and be it further

"*Resolved*, That the Board of Direction recommends, to the Business Meeting to be held at the Annual Convention, the adoption of the following resolutions:

"*Resolved*, That the Board of Direction be authorized to ascertain whether suitable accommodations can be obtained for the Society in the proposed new building, with provisions for future needs, and also to make such investigations and hold such conferences as may bear upon the advisability of the acceptance of Mr. Carnegie's proposition by this Society.

"*Resolved*, That the Board of Direction be authorized to co-operate to this end with the other organizations concerned.

"*Resolved*, That the Board of Direction be requested, provided it is satisfied that suitable accommodations can be obtained, and that the acceptance of the proposition is otherwise practicable, to send to the members of the Society a letter-ballot by means of which a direct expression of the wishes of the Society in the matter may be secured, and to accompany such ballot by a statement of reasons for and against uniting in the scheme with the other organizations.

"*Resolved*, That the Board of Direction, in case a majority of the members, as shown by letter-ballot, are in favor of uniting with the other organizations, is authorized to proceed in behalf of the Society in carrying out the project."

The following resolution was then offered by Mr. Hansel:

"*Resolved*, That the American Society of Civil Engineers acknowledge the offer from Mr. Carnegie, and thank him sincerely for the opportunity, and advise him at the same time of the action to-day, and that the object of this delay is to determine and consider every feature of the situation carefully before deciding the matter."

The motion, being duly seconded, was carried.

After certain announcements relative to the programme had been made, the Business Meeting adjourned.

Second Session, Tuesday, June 9th, 1903, 8 P. M.—The meeting was called to order at 8 P. M., President Alfred Noble in the Chair; Chas. Warren Hunt, Secretary.

The President delivered the Annual Address.

Third Session, Wednesday, June 10th, 1903.—At the close of the Business Meeting the discussion of Engineering Topics was taken up.

Discussion on the first topic, "Timber Tests," was opened by W. K. HATT, Assoc. M. Am. Soc. C. E., on behalf of the United States Bureau of Forestry. Written discussions by Messrs. Gaetano Lanza and H. von Schrenk were not read, owing to the lateness of the hour. The topic was further discussed by the following:

A. L. JOHNSON, M. Am. Soc. C. E.
S. BENT RUSSELL, M. Am. Soc. C. E.

The meeting then took up the discussion of the second topic, as follows:

"Sewage Purification."

The subject was opened by a written discussion from RUDOLPH HERING, M. Am. Soc. C. E., presented by the Secretary.

Adjourned.

Fourth Session, Thursday, June 11th, 1903.—The meeting was called to order at 9.20 A. M., President Alfred Noble in the chair; Chas. Warren Hunt, Secretary.

The President introduced the Hon. Charles B. Aycock, Governor of North Carolina, who spoke as follows:

Ladies and Gentlemen: The suggestion of your President, that I address you this morning, takes me by surprise. I am not going to do that. I wish it had been my good fortune or that I had fitting occasion to have had the opportunity of expressing to you, in behalf of North Carolina, our appreciation of your coming among us. The good fortune of doing that rested with my good friend, General Davidson. What he has once done no man can do better, and I will not attempt, again, to put into fitting phrase the cordial welcome which all North Carolina extends to you. We are glad to have you with us. We take it as an honor that this learned Society should meet in our midst, and we know that we will find profit in your deliberations.

Now, I do not know anything about the work which you all do. There are some things, however, which it has been my observation that you have not yet accomplished, and to which I hope you will give your attention. In all your studies I hope that you will have in view that great body among whom I am a small particle, the consumers, and that you will be able in the future to unravel the mystery which controls the gas, water and electric meters, and I commend, Mr. President, to your most careful consideration, the study of the operation of a water meter which continues running long after the water has been shut off. I believe the old song tells us that the wheel is not driven by the water that has passed,

but that is the water that we see on the outside; it continues to run on the inside (laughter). And when you have accomplished that purpose, why, we shall owe you a debt of gratitude that we can never repay.

But your deliberations are of value. They are of value to all the world. You have been of great service to this country as have the representatives of your great association in our State. There is no man whom we esteem more than your representative, Mr. Ludlow, who has been instrumental in bringing you here, and he, I am sure, has added to your comfort and pleasure. Again, I wish to express to you my appreciation of your coming among us, to express the hope that you will stay a long time, and to assure you that the longer you stay, the better we shall like you.

The Governor of this State is clothed with ample power to pardon you for any offense that you may want to commit. (Laughter and applause.) It has not been the custom of North Carolina governors to issue pardons in advance, but, looking into your faces, I promise you now to pardon you for any offense which any one of you may commit while within our borders; with one single exception, however, and that is, if you should leave us without regarding Asheville as the finest place in the universe, without regarding North Carolina as the best State in the Union, without wanting to come back and stay with us and be with us again – for that I cannot pardon you; (applause) for this is a beautiful section, and when you have seen Asheville, any Ashevillian will tell you that you have seen North Carolina, but North Carolina extends one hundred miles to the west of here and five hundred miles to the east. If you were to swing this good State of ours on Murphy as a pivot—Murphy lies one hundred and twenty miles west of here—Chocowinity, on our eastern coast, would rest on the spot that Chicago now tries to fill. (Laughter and applause.)

This is a State that we are very proud of, and we want you to know more about it. We are proud of her history, and would you regard it as offensive in me if I reminded you just for a moment of some of the history of which we are proud?

This State of ours was the first colony that was settled. The colonization was not a success, but we were colonized at first under the auspices of that great and good man, Sir Walter Raleigh, and we have named the capital of our State for him, not for his great achievements, understand, not for his wonderful learning, not for his statesmanship, not for his seamanship, but we have named the capital of this State in his honor for one simple little act, for we read in history that that great man, when he saw his queen about to wet her feet, dropped the rich cloak from his shoulders in order that she might walk dryshod across; (applause) and it is in memory of that deed, in the love of the woman, that we have named our capital after him.

It was this good State of ours that had the first Tea Party that was held in the Colonies. The Tea Party at Boston has been celebrated in song, in history, in romance, but the North Carolina Tea Party at Edenton, when the North Carolina Colonial Dames resolved that they would drink no more tea as long as the hated tax remained on it, is known to few outside of the borders of this State. And we had another Tea Party down on Cape Fear, three or four hundred miles from here, a Tea Party in which the men of old Cape Fear, in the broad open daylight, in the presence of the Royal Governor, took the stamp clerk and swore him that he would bring no more stamps into the Colony of North Carolina forever.

It was in this State of ours that the first victory was won in behalf of America—the battle of Moore's Creek, in Pender County. It was in this State of ours that the first Declaration of Independence was ever written; the Mecklenburg Declaration of Independence of the 20th of May, 1775. So that we are glad to welcome you to this historic place.

Along the lines of industrial activity, along the lines of commerce, along business lines, we have not kept pace with other States, but we have caught the step, and the future in this State shall furnish opportunities to men of your profession, and your profession will make us successful in many of the departments of life.

Again I greet you and thank you for the opportunity of looking into your faces and gathering further and renewed hope for North Carolina in the work which you do. (Applause.)

At the conclusion of the address, B. M. Harrod, Past-President, Am. Soc. C. E., opened the discussion of the third topic:

"In the Treatment of the Mississippi River, is the Levee Theory Justified by Experience?"

The Secretary read a communication on the subject from J. A. Ockerson, M. Am. Soc. C. E., and Samuel Tobias Wagner, M. Am. Soc. C. E., presented briefly the views of Lewis M. Haupt, M. Am. Soc. C. E.

Owing to lack of time the written discussion of L. W. Brown, M. Am. Soc. C. E., was not read.

The meeting then took up the discussion of the topic:

"Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?"

The subject was discussed by the following:

R. W. Lesley, Assoc. Am. Soc. C. E.
J. J. R. Croes, Past-President, Am. Soc. C. E.
J. W. Schaub, M. Am. Soc. C. E.
B. R. Green, M. Am. Soc. C. E.
O. Lowinson, Assoc. M. Am. Soc. C. E.
W. K. Hatt, Assoc. M. Am. Soc. C. E.

The Secretary read a communication on the subject from Mr. Edward Cunningham.

It was moved by J. W. Schaub, M. Am. Soc. C. E., that it is the sense of this meeting that a Special Committee be appointed to take up the question of concrete and steel-concrete, and that such committee co-operate with the Association for Testing Materials, and the Railway Engineers' Maintenance of Way Association, which also have a committee on this subject.

The motion, being duly seconded, was carried.

The next topic discussed was:

"In View of the Increasing weights of Rolling Stock, for what loadings should Railroad Bridges be designed?"

The discussion was opened by a communication from H. W. Hodge, M. Am. Soc. C. E., read by the Secretary; and was added to by the following:

J. W. Schaub, M. Am. Soc. C. E.
E. Swensson, M. Am. Soc. C. E.
T. L. Condron, M. Am. Soc. C. E.

It was moved by George W. Catt, M. Am. Soc. C. E., and seconded by B. R. Green, M. Am. Soc. C. E., that a committee be appointed to draft a series of resolutions of thanks to the several parties who have kindly entertained the Society at Asheville.

The motion was carried, and the President appointed Messrs. George W. Catt, H. S. Haines and B. R. Green.

Adjourned.

The following resolutions were prepared by the Committee and have been transmitted in accordance with the action of the Convention:

"*Whereas*, The Thirty-fifth Annual Convention of the American Society of Civil Engineers, at Asheville. N. C., June 9th–12th, 1903, will long be remembered by those who were fortunate enough to be present, as a most delightful social occasion.

"*Resolved*, That the thanks of the Society are hereby heartily tendered to the Local Committee of Arrangements, and particularly to its Chairman, J. L. Ludlow, M. Am. Soc. C. E., for the careful preparation, and successful carrying out, of the attractive programme."

"*Resolved*, That the thanks of the American Society of Civil Engineers are hereby cordially tendered to the Swannanoa Country Club, for courteously placing its interesting Golf Links at the disposal of the members and guests of the Society during the Thirty-fifth Annual Convention of the Society, June 9th–12th, 1903, and for hospitably throwing open its Club House to all who attended the Convention."

"*Resolved*, That the thanks of the American Society of Civil Engineers are hereby cordially tendered to the Asheville Club for courtesies extended to its members during the Thirty-fifth Annual Convention of the Society, June 9th–12th, 1903."

"*Resolved*, That the thanks of the American Society of Civil Engineers are hereby heartily tendered to W. F. Randolph, Esq., Secretary, Asheville Board of Trade, for his energetic efforts to add to the pleasure and comfort of all who attended the Convention, which were entirely successful, and very much appreciated."

"*Resolved*, That the thanks of the American Society of Civil Engineers are hereby tendered to the Asheville Electric Company for many courtesies extended to its members and guests on the occasion of its Thirty-fifth Annual Convention, June 9th–12th, 1903."

"*Resolved*, That the thanks of the American Society of Civil Engineers, and particularly of those who were so fortunate as to be present on the occasion referred to, are hereby tendered to Richard S. Howland, Esq., for the courtesy of his invitation to visit Overlook Park on Sunset Mountain, on June 11th, 1903, as well as for the hospitable 'Barbecue' which added so much to the pleasure and comfort of that occasion."

OF THE BOARD OF DIRECTION.

(Abstract.)

June 2d, 1903.—8.40 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Craven, Croes, Knap, Kuichling, Meade, Pegram, Schneider, Swain and Wilgus.

The thanks of the Board of Direction of the Society were voted to Charles Paine, Past-President, Am. Soc. C. E., for the presentation, in accordance with the request of the Board of Direction, of an oil painting of himself.

A report was received from the Committee appointed to attend the meetings of a Joint Conference Committee from other societies, and the Engineers' Club, presenting certain resolutions for the consideration of the Society.*

Resolutions for presentation to the Business Meeting of the Annual Convention were adopted †

Applications were considered and other routine business transacted.

One candidate for admission as Associate, and five as Juniors were elected.‡

Adjourned.

June 9th, 1903.—The meeting of the Board, as required by the Constitution, was called at 9.30 P. M.

There were present Messrs. Noble, McDonald, Osborn, Pegram, Schneider and Hunt.

Inasmuch as a quorum of the Board at meetings convened at Annual Conventions is nine, no quorum being present, the meeting adjourned.

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* See page 224.
† See page 226.
‡ See page 193.

REPORT IN FULL OF THE FIRST SESSION OF THE THIRTY-FIFTH ANNUAL CONVENTION, INCLUDING THE BUSINESS MEETING, HELD AT THE BATTERY PARK HOTEL, ASHEVILLE, N. C.

Tuesday, June 9th, 1903.

The meeting was called to order at 2.30 P. M. by J. L. Ludlow, M. Am. Soc. C. E., Chairman of the Local Committee.

Address of Welcome, J. L. Ludlow.

J. L. LUDLOW, M. Am. Soc. C. E.—Ladies and Gentlemen: As Chairman of the Local Committee of Arrangements, I have been allotted the privilege and pleasure of opening this, the Thirty-fifth Annual Convention of the American Society of Civil Engineers in the State of North Carolina. As a privilege, it is one that I appreciate highly; as a pleasure, it is one, the appreciation of which it is impossible for me to express. Not only words would fail me, but all the theorems, the formulas, the figures, ever thought of, conceived or used by the minds of those devoted to the art and science of engineering would not be able to express to you the pleasure that I feel in the honor which is thus conferred upon me. (Applause.)

Of North Carolina, the hospitality of which is as ancient as—well, say the Pyramids of Egypt—as unbounded as the atmosphere and the skies above us, as an adopted son, I would gladly address you, but of that it is not my privilege at this time to speak. I may, however, express one thought to prove my assertion of the limitless hospitality of North Carolina by reminding you, that when Fate decreed the most suitable birthplace for the first white child of America—the place that should be honored of all the American continent—Roanoke Island, in North Carolina, where even the Indians were found to be hospitable and kind, was the birthplace of Virginia Dare.

I have the honor of presenting to you one whose oratory and brilliant attainments are well known; a gentleman native and to the manner born, a typical North Carolinian who has been highly honored by his State, and returns a full measure of honor to her; one who exemplifies a lofty type of manhood in full harmony with the summits of Nature which surround us in this beautiful mountain region, that is so fittingly called the "Land of the Sky." He will speak to you a hearty welcome to the State of North Carolina and to the City of Asheville. I have the honor to present General Theodore F. Davidson. (Applause.)

Address of Welcome, Gen. Davidson.

GEN. THEODORE F. DAVIDSON.—Mr. President, Ladies and Gentlemen: Should any of you have come here expecting to hear an oratorical display from me, or should any of you have been encouraged in an expectation, not very well formed beforehand, by what my friend, Mr. Ludlow, has said, I am sure that you will meet with a very serious disappointment.

It has been Asheville's good fortune to receive and entertain, Mr. President, many distinguished men, associations and societies, repre-

senting almost every phase of the intellectual, the moral, the political, the scientific and industrial life and progress of this most marvelous age. I think I can say to you this afternoon truthfully, Mr. President, that no occasion has been more fruitful of pleasant anticipations, no event has excited greater interest, with a very large portion of this community, than the convention in Asheville of the American Society of Civil Engineers.

We recognize and appreciate the high privilege of having with us one of the most learned and famous scientific societies of the world; perhaps, I am told, and I have no doubt it is true, there is but one other organization, purely scientific, in the world, which compares with it in importance and in achievement; a society whose membership represents, not only the Western Hemisphere, but which has its representatives wherever Christendom prevails; whose influence encircles the whole globe, whose genius and achievements are visible in every land and upon every sea.

It is the peculiar fortune, Mr. President, of your profession—the exceptional distinction of the science of engineering in its broadest sense—that in every period, at every stage of the progress of mankind, from savage conditions to civilization, it has been the most potent factor and agent; and what is especially fortunate for you is that it has been able to perpetuate its history and its influence by the creations of its genius, so great and so enduring that they are universally recognized as the mile-stones of history. If the literature, the political policy, the social and intellectual organizations of the ancient civilizations are either entirely lost to us or so veiled by the dust of centuries as to be fabulous, the engineer of the time of the Pharaohs gave us the Pyramids, and it has come to pass here to-day that our debt to the Pyramids is very much greater than scientific, for they are admirable for the purpose of reference on occasions of this sort. (Applause.) The enduring evidence of skill in the science of construction, the splendid remains of the cities of Asia, of the wonderful irrigating systems of China—even of the semi-civilized Peruvians—the construction of artificial ports for the advancement and protection of commerce as at Ostia and Piræus, Alexandria, Carthage, and all along the shores and the islands of the Mediterranean—the wonderful examples of the science of fortification at Syracuse, ascribed, I believe, to Archimedes; the highways and aqueducts of immortal Rome; the unapproachable beauty and glory of St. Peter's dome and Florence's Campanile, are the enduring illustrations and records of your profession in the past.

It has been said, I believe, that so far had your predecessors pushed the development of your science at the close of the eighteenth century that the opportunities for its further advancement and exploitation had reached a conclusion, and there were no fresh fields to explore or opportunities for new applications of principles of

Address of Welcome (continued).

engineering. However that may have been, with the discovery of steam as a motive power, a new, a vast and as yet only partly occupied field for the employment and advancement of the science of engineering was displayed. How quickly that opportunity was seized, how generously and magnificently it has been utilized, how great have been the blessings you have been able to confer upon your age need no recital now; we have but to look around us to see them in every direction. We take no step, individually or collectively, but we feel their benign influences. Most truthfully has it been said that the mission and achievements of the engineer are the subjection and control of the forces of Nature to the uses and happiness of mankind.

The traveler who is carried safely and comfortably for miles under the Alps; who is transported with equal comfort and safety through the air across the yawning chasm of Niagara, or the turbulent tides of the Forth; the merchant who securely floats his valuable cargoes through the Suez Canal, or the Mississippi Jetties; or harbors them in the great docks of London, Liverpool, Antwerp, Bremen, Marseilles, or New York; the mariner who now confidently navigates every sea and finds on every dangerous shore ever-vigilant sentinels against danger, as well as the most careful provision for his comfort and safety—all are either the conscious or unconscious beneficiaries or the thankful beneficiaries of your professional skill.

It would be an impossible task for me, with unlimited time at my command, to portray as they should be portrayed your efficient labors in the various avenues of our modern domestic, social and industrial life. You pierce the clouds and the skies with the sky-scrapers devoted to commerce and domestic life. If you cannot fling your spans of bridges across the Hudson you can ignore that stream by tunneling beneath it and connecting states, empires and nations without trouble from the intervention of natural obstacles. In the way of hygiene, sanitation, municipal development and all the agencies which go to evolve and bring under subjection the natural resources, not only of this new continent, but of the old, you are the pioneers and will ever be the pioneers necessarily, because it is the necessary incident to the practice of your profession.

Your past, at least, is secure. Your future I believe to be more brilliant, to be fuller of the possibilities of greater scientific development and usefulness to the world. On this continent, not to mention other things, you are now to assume the gigantic work of the construction of an isthmian canal, with all its vast and incomprehensible consequences, to commerce, to policies and to peoples; you are called upon as Americans representing the American Society of Civil Engineers to take up the great work of reclaiming a vast area of our country, an arid area, from the desert of desolation, and make it the valley of untold productivity. The possibilities of the uses of electricity lie just

before you, without it being in the ken of man to say what shall be the limits of those possibilities. The world waits upon you; you will ever be in the forefront, we are confident, in the future as in the past, of every movement for the advancement of knowledge, the progress of civilization and the happiness of mankind.

You will understand, therefore, Mr. President, and Ladies and Gentlemen, why we, the citizens of North Carolina, and especially of this little city in the mountains, welcome your coming with unusual interest, and I can only say in behalf of those people, and express the hope that the pleasure and profit we derive from your coming together here now will, in some degree, approach the feeling of thankfulness that the citizens of Asheville and of the State of North Carolina, I may add, entertain for the very great honor that you have done them in your coming together here, and, to quote the language that old Colonel Buncombe, for whom this County was named, inscribed upon his mansion in eastern North Carolina in the colonial days, "To Buncombe Hall, Welcome All." (Applause.)

ALFRED NOBLE, President, Am. Soc. C. E.—General Davidson, I accept, on behalf of the American Society of Civil Engineers, the most gracious welcome which you have accorded us. Our anticipations have been raised very high by the eloquence of our member, Mr. Ludlow, as he sought in glowing words to depict the attractions of this city in the mountains. For your hearty welcome we can only return our most fervent thanks. We appreciate very gratefully the kind words that you have been pleased to express in regard to our chosen profession, and if we may not reach the high ideals which you have placed for us, we must never forget that we must strive to come as near them as possible. With the sincerest thanks, General Davidson, we receive your welcome in a spirit no less cordial than that in which you have expressed it. (Applause.)

BUSINESS MEETING.

President Noble in the chair; Charles Warren Hunt, Secretary.

THE PRESIDENT.—The Society will now come to order for its regular business meeting. The first question before the Society is the time and place for holding the next Annual Convention.

Convention of 1904.

THE SECRETARY.—It having been practically understood at previous business meetings that the Convention of 1904 should be held in St. Louis during the Louisiana Purchase Exposition, the customary ballot was not sent out this year to members asking their preferences as to where the Convention should be held. It has been customary in the past that a discussion of the time and place for holding the next Annual Convention should take place each year at the Annual Convention. The usual course has been to express the views of the business meeting, and then to refer the matter with power to the Board of Direction.

I have, in that connection, Mr. President, received some letters in regard to St. Louis.

THE PRESIDENT.—The Secretary will read them, if there is no objection.

Letter from D. R. Francis.

THE SECRETARY.—I will read a letter addressed to the President of the Society, dated May 15th, by Mr. D. R. Francis, President:

"ST. LOUIS, U. S. A., May 15, 1903.

"*To the President of the American Society of Civil Engineers,*

"SIR:—

"On behalf of the Louisiana Purchase Exposition I desire to extend to the American Society of Civil Engineers a cordial invitation to hold the annual meeting of the Society for 1904, in the City of Saint Louis.

"In that year will be held at Saint Louis the Universal Exposition in commemoration of the one hundredth anniversary of the Purchase of Louisiana Territory. The Exposition management will be prepared to furnish without charge a satisfactory hall, for the holding of the sessions of the Society. The Committee on Ceremonies will, if desired, recognize the presence of the American Society of Civil Engineers by setting apart a special day, or by providing some distinctive feature of the program.

"The Information Service, conducted without charge by the Exposition management, will assist delegates in obtaining satisfactory accommodations at reasonable prices. The fair name of Saint Louis for hospitality will not be marred in 1904. Assurances given by the railroads warrant the promise of very low rates of transportation.

"Respectfully,

"D. R. FRANCIS,
"*President.*"

Letter from C. P. Walbridge.

Also a letter dated May 18th, from the Business Men's League, C. P. Walbridge, President:

"ST. LOUIS, May 18, 1903.

"*To the President of The American Society of Civil Engineers, In Session at Asheville, N. C.*

"SIR:—

"The Business Men's League of St. Louis has the honor to extend an invitation to the American Society of Civil Engineers to hold its Convention in 1904 in St. Louis. The great Louisiana Purchase Exposition will then be open, and the city will be most attractive. The hotel and hall accommodations will be adequate, and railway rates will be low. "Very truly yours,

"C. P. WALBRIDGE,
"*President.*"

"WM. FLEWELLYN SAUNDERS,
"*Secretary and General Manager.*"

Letter from Rolla Wells.

Also a letter from the Mayor of St. Louis:

"ST. LOUIS, May 20, 1903.

"*To the Honorable President and Members of The American Society of Civil Engineers, Asheville, N. C.*

"GENTLEMEN:—

"In behalf of the City of St. Louis, I take pleasure in extending to your Society a cordial invitation to hold your annual meeting for the year 1904, in this city.

"Very truly,

"ROLLA WELLS,
"*Mayor.*"

Also a letter dated May 22d, addressed to the President, by the local members of the American Society of Civil Engineers, and by J. A. Ockerson, a member of this Society: Letter from J. A. Ockerson.

"St. Louis, Mo., May 22, 1903.

"Mr. Alfred Noble,
President, American Society of Civil Engineers.

"Dear Sir:—

"At a recent meeting of the local members of the American Society of Civil Engineers, also at a meeting of the St. Louis Engineers' Club, I was requested to extend, in their behalf, a most cordial invitation to the American Society of Civil Engineers to hold its Annual Convention of 1904 in this city, and I now take great pleasure in doing so.

"In addition to these invitations, I enclose herewith invitations from the Business Men's League, the Mayor of the City, and the President of the Louisiana Purchase Exposition.

"It is something more than twenty-three years since the Society met in this city, and it is believed that the celebration of the anniversary of the Louisiana Purchase, by a Universal Exposition next year, will make this city particularly attractive as a meeting place. It is hoped, therefore, that these invitations will be presented to the Society at the next Annual Convention and receive favorable consideration.

"Yours very respectfully,

"J. A. Ockerson,
"*M. Am. Soc. C. E.*"

The President.—The subject is now before the Convention.

Henry B. Seaman, M. Am. Soc. C. E.—Mr. President, the discussion of the subject hardly seems necessary, as the Secretary says it has been previously under discussion, and I move that the matter be referred to the Board of Direction, with power to act.

The motion was seconded and carried.

The President.—The next subject before the Convention is the proposed Amendment to the Constitution, which the Secretary will read.

The Secretary presented the amendment, as follows:

Amend the Constitution by striking out Sections 6, 7 and 8 of Article II, and the whole of Article III, and substituting therefor the following: Amendment to the Constitution.

ARTICLE II.—Membership.

* * * * * * * *

6.—A Junior shall not be less than eighteen years of age, and his connection with the Society shall cease when he becomes thirty years of age, unless he be previously transferred to another grade. He shall have had active practice in some branch of engineering for at least two years, or he shall have graduated from a school of engineering of recognized standing. Persons who are in the Junior class at the time of the adoption of this Constitu-

Amendment to the Constitution (continued).

tion shall not have their status changed by the provisions of this section.

7.—Honorary Members shall be chosen only from persons of acknowledged eminence in some branch of engineering or the sciences related thereto. There shall not be more than twenty at any one time.

8.—Fellows shall be contributors to the permanent funds of the Society, though they may not be eligible for admission as Corporate Members.

ARTICLE III.—Admissions and Expulsions.

1.—Honorary Members shall be proposed by at least ten members, and shall be elected only by a unanimous vote of the Board of Direction. A Past-President, or a member of the Board of Direction proposed for Honorary Membership, shall not be required to vote either for or against his own admission.

A person elected an Honorary Member shall be promptly notified thereof by letter. The election shall be cancelled if an acceptance is not received within six months after the mailing of such notice.

2.—An application for admission to the Society or for transfer from one grade to another shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected. The applicant shall furnish the names of at least five Corporate Members to whom he is personally known. Each of these shall be requested by the Secretary to address a letter to the Board of Direction, on a form prescribed by said Board, stating the extent of the writer's personal knowledge of the applicant and of his professional work. If at least five of the Corporate Members named as references do not furnish the requisite endorsement, the Secretary shall call upon the applicant for additional names, and not until written communications shall have been received from at least five Corporate Members shall the application be considered by the Board.

Applications of engineers not resident in North America, and who may be so situated as not to be personally known to five Corporate Members, may be recommended for ballot by five members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

3.—At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for admission or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries,

if deemed expedient; shall classify the applicant with his consent, and on applications for admission may direct a ballot.

The Board shall have the power to transfer persons from a lower to a higher grade of membership, and shall notify the membership of its action.

4.—The ballots shall be letter-ballots, in a form to be prescribed by the Board of Direction. They shall be mailed to each Corporate Member whose address is known, and shall state the date on which the ballot is to be canvassed, which shall be not less than twenty days after the issue of the ballot. Twenty or more negative votes shall exclude from election. In case of exclusion, no notice thereof shall be entered on the minutes, but the candidate shall be notified.

5.—All elected candidates shall be duly notified and shall subscribe to the Constitution and Rules of the Society. Forms for these purposes shall be prescribed by the Board of Direction. If these provisions are not complied with within six months from the notification of election, such election shall be considered void, unless for special reason the time shall be extended by the Board of Direction.

Membership of any person shall date from the day of his election.

6.—Upon the written request of ten or more Corporate Members, that for cause therein set forth a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He may, if he so desires, present a written defence which shall be considered at a meeting of the Board of Direction, of which he shall receive due notice. Not less than two months after such meeting, the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a defence made which is satisfactory to the Board, it shall then notify the person that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Corporate Members by letter-ballot in a form to be prescribed by the Board of Direction. The ballot shall be accompanied by a statement of the charges, and of the action of the Board thereon, with such information as it deems proper, and also the statement of the person making the appeal. The ballot shall be canvassed by the Board not less than twenty days after its issue A majority of the ballots cast will be required to sustain the action of the Board. The Board will notify the person and the Corporate Members of the result of the ballot. In case no appeal be made, the Board of Direction will expel the person, and notify him and the Corporate Members of its action.

7.—A member of any grade in the Society may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Direction; when, if all his dues have been paid, his resignation shall be accepted.

8.—All persons elected and duly qualified, whose address on the records of the Society is within fifty miles of the Post Office in the City of New York, shall be deemed Resident; and those whose address is beyond that limit shall be deemed Non-Resident.

The classification of each person for the fiscal year as Resident or Non-Resident, shall be determined by the Records of the Society as they may appear on January 1st of that year.

Amendment to the Constitution (continued).

The above amendment is proposed by the following Corporate Members:

JOHN F. WALLACE,	GEO. S. DAVISON,
DAVID SLOAN,	EMIL SWENSSON,
RALPH MODJESKI,	J. A. ATWOOD,
J. W. SCHAUB,	W. C. HAWLEY,
ALBERT F. REICHMANN,	W. G. WILKINS,
C. A. HASBROUCK,	JOSIAH A. BRIGGS,
FRANK J. LLEWELLYN,	J. J R. CROES,
CHARLES L. STROBEL,	A. NOBLE,
GEO. F. SWAIN,	H. S. HAINES,
WILLIAM JACKSON,	JOS. O. OSGOOD,
JOHN E. CHENEY,	GEO. H. PEGRAM,
S. EVERETT TINKHAM,	EDW. P. NORTH.

THE PRESIDENT.—Would it not be as well to give a concise statement as to the effect of this amendment?

Discussion on Amendment to the Constitution.

THE SECRETARY.—The first three sections of Article II are identical with the present Constitution, with the exception that the original Constitution states that in applications for admission of Juniors the applicant shall state that he intends to become or continue to be an engineer. The reason for taking that out is that this present amendment contemplates that no applicant, whether for Junior or for Member, shall make an application for any definite grade, and in the old Constitution it would require him to specify in the body of his application that he applies for junior membership. It is merely to make the matter conform with the remainder of the article.

Section 1 of Article III, relating to Honorary Members, is identical with the present Constitution; there is no change made.

Section 2 of Article III, relating to applications, is changed so that all applications received are applications for admission to the Society, not for admission as Member, Associate Member, Associate, Junior, or Fellow; and the whole intent of this section is to print in the preliminary list—what we call the blue list—the preliminary notice of candidacy, in an alphabetical list, all applications for membership exactly as is now done, with the names of references given, except that they shall not specify that some of them are for Member, some for Associate Member, some for Associate, some for Junior, and so on.

After exactly the same process as is now in vogue is gone through with by the Board of Direction, the Board classifies the applicant, and, having secured his consent to that classification, issues his name on a ballot list, exactly as at present, to all the members.

A MEMBER.—That includes Juniors too, does it?

THE SECRETARY.—Yes, that is as it stands at the present time. The next clause gives the Board the power to transfer persons from a lower to a higher grade without a further vote of the membership of the Society, and simply states that they shall notify the Society of that action. Under the present system, if a member is elected a Ju-

nior, he must again be elected an Associate Member, because he cannot transfer from Junior to full membership, and it is quite possible (and it has been done) that a man is elected to the Society by the membership three times.

The next clause is identical with the present clause of the Constitution in regard to letter-ballots, with the exception that, instead of seven negative votes excluding, the provision of this amendment is that there shall be twenty votes necessary for the exclusion of a candidate. Those are the only changes, Mr. President, except that in this amendment the present reconsideration ballot is entirely done away with. Under the present system the ballot on a candidate excluded by seven negative votes can be reconsidered upon the request of eight Corporate Members, and, having gone through the regular form, he can be elected, providing 10% of all the ballots cast, which are signed ballots, are not against him. In other words, while it is possible for a candidate, under the present Constitution, to be defeated with fifteen votes against him, it is also possible, and I may say that I believe it has been done, that a candidate has been elected with forty odd votes against him on the pink ballot. It simply depends on the number of ballots that come in. It is the percentage of the ballots cast. In this amendment the pink ballot is done away with entirely.

G. W. Tillson, M. Am. Soc. C. E.—How soon can one come up for admission again if rejected?

The Secretary.—There is no specification, sir, in this amendment as offered.

The President.—The amendment is now before the Society for amendment.

J. J. R. Croes, Past-President, Am. Soc. C. E.—Mr. President, the first clause of Article III is rather indefinite. It provides for the admission of an Honorary Member, but there is nothing in the section thereafter which states precisely the manner in which a candidate for membership shall be admitted to the Society. I would move that there be added a third clause to Section 1 of Article III to read as follows:

"All members other than Honorary Members and Juniors shall be admitted to the Society only by vote of the Corporate Members as hereinafter specified."

That covers the method of admission to the Society which is not contained in any other part of the Constitution.

A Member.—How about Associates?

Mr. Croes.—Associates are elected by a vote of the Corporate Members. As stated in the rest of the Constitution, all applicants make application simply for membership. The Board classifies them. The Society elects them. If they are classified as Members, as Associate Members, or as Associates, the ballot goes out for the person in that

Discussion on Amendment (continued).

grade, and, in the present form of the amendment, it provides for the election of Juniors in the same way. I wish to move an amendment also to the second paragraph of Section 3 of Article III.

THE PRESIDENT.—Would it not be best to take action on the proposed amendment first?

MR. CROES.—Well, yes; the first amendment I offer is this one, defining simply the manner in which members are admitted to the Society.

GEORGE H. PEGRAM, M. Am. Soc. C. E.—I second the motion, Mr. President.

A MEMBER.—How are Fellows to be elected?

THE PRESIDENT.—Will Mr. Croes answer the question?

THE SECRETARY.—Under this amendment, sir, by general vote, even if Mr. Croes' amendment passes.

MR. CROES.—Fellows shall be contributors to the permanent funds of the Society though they may not be eligible for admission as Corporate Members.

A MEMBER.—And they are elected by ballot?

THE SECRETARY.—Under this amendment; yes, sir.

MR. SEAMAN.—Mr. President, by this proposed amendment, a Junior does not come up for general ballot. He is elected by the Board. The Board can then, in a year or so, transfer him to full membership.

MR. CROES.—If the gentleman will pardon me, there is an amendment referring to that which the President directed should not be read at this time. I would state, though, that the amendment which I propose to offer in connection with that subject, after this amendment has been acted upon, is that the Board shall have power to elect persons to the grade of Junior and to transfer persons from any grade except that of Junior to a higher grade of membership. Those two go together, but they are separate amendments. If you adopt the first one you want to adopt the second one, too.

B. R. GREEN, M. Am. Soc. C. E.—How are Associates elected now?

MR. CROES.—By the Board.

MR. GREEN.—According to this proposed amendment, they are elected by the Society.

MR. CROES.—By the Society, yes.

MR. GREEN.—Is that desirable?

MR. CROES.—Yes. The question has been asked how Fellows are elected now?

THE SECRETARY.—They are elected by the Board, sir, just the same as Juniors and Associates.

MR. GREEN.—This makes them elected by the Members?

THE SECRETARY.—It makes every man elected to a permanent grade

in the Society elected by the membership at large. It allows the Board to elect a Junior, whose term as a Junior ceases when he becomes thirty years of age, and, consequently, as it is not a permanent grade, Mr. Croes proposes to have him elected by the Society again into one of the permanent grades.

THE PRESIDENT.—Are you ready for the question? If there is no further discussion, the chair will put the question.

The question was put and carried.

MR. CROES.—Now, Mr. President, I offer the amendment to the second paragraph of Section 3, Article III. It now reads:

"The Board shall have the power to transfer persons from a lower to a higher grade of membership, and shall notify the membership of its action."

The amendment is, that the Board shall have the power to elect persons to the grade of Junior and to transfer persons from any grade except that of Junior to a higher grade of membership, and shall notify the membership of its action. It does not seem to me to be advisable to have the Juniors elected by the Society, but to have the Juniors elected by the Board, and when they want to go higher, their election by the Society takes place. That covers the question which Mr. Seaman asked.

The amendment was seconded.

THE PRESIDENT.—The amendment to the amendment is seconded. It is now before the Society for discussion. If there is no discussion, the Chair will put the question.

The question, being put, was carried.

THE SECRETARY.—I have a communication which I would like to read. It is from Mr. James Burden, an Associate Member of the Society.

Letter from James Burden.

"TROY, NEW YORK, May 3, 1903.

"MR. CHARLES WARREN HUNT,
Secretary Am. Soc. of C. E.,
New York.

"DEAR SIR:

"I am in receipt of the proposed amendment to the Constitution.

"In Article II, Section 6, it says of the Junior Member, that 'his connection with the Society shall cease when he becomes thirty years of age.' This is as the case now stands, and it has always seemed to me unfortunate. In nearly every class in an engineering school are some men who graduate so near this limit that they cannot avail themselves of the advantages of Junior membership, as they would not at thirty be eligible for Associate membership, yet these men are not infrequently those who have had to fight their own way, and are keenly in earnest in their professional work. It seems to me that the limit might well be thirty-five years. This would prevent no one from applying earlier for a higher grade.

"I have known application for Junior membership to be advised on the ground that at thirty a man would probably be admitted to

Discussion on Amendment (continued).

Associate membership who might be rejected if he were outside of the Society. If the limit were thirty-five he could be made to wait or would probably elect to do so himself.

"Very truly yours,

"JAMES BURDEN,

"Assoc. M. Am. Soc. C. E."

At Mr. Burden's request, I offer for him the amendment to change the word "thirty" to "thirty-five."

THE PRESIDENT.—Is the proposed amendment seconded?

The amendment was seconded.

THE PRESIDENT.—It is now before the Society for discussion.

H. F. WILSON, Jr., Assoc. M. Am. Soc. C. E.—Mr. President, it seems to me that thirty-five makes a man wait rather late in life. What is the matter with thirty-two or thirty-three?

MR. SEAMAN.—I think that is a good suggestion, Mr. President. I think thirty is the age which we should reach; but there is the objection suggested by Mr. Burden, and those on the Board are familiar with the fact that we often have to make special rulings, or rather the Board has often to make special rulings, to cover those special contingencies. I would move that the age of thirty be changed to the age of thirty-two.

THE PRESIDENT.—The motion is that the age be changed from thirty to thirty-two.

THE SECRETARY.—On behalf of Mr. Burden, acting for him as nearly as I can do in his absence, I will accept the amendment. I think it covers the ground that he intended to cover.

THE PRESIDENT.—If there is no objection, the age of thirty-two will be accepted in lieu of the age of thirty-five. Is there any discussion on the proposition as it now stands?

MR. WILSON.—It seems to me, Mr. President, that thirty-three would be better. The change is very little from thirty to thirty-two. It strikes me that if a man is going to get out of college at all he will get out at the age of thirty years, and he will then have two years in the Junior grade before he can go into the grade of Associate Member.

THE SECRETARY.—If I am allowed one more word, I think the only objection to changing the time at which a Junior ceases to be a Junior of the Society is that, under the present Constitution the age at which he ceases to be a Junior is coincident with the age at which he becomes eligible for membership. Consequently, it is impossible for a Junior to transfer from the grade of Junior to the grade of Member under our present Constitution. That has elements of propriety, however, inasmuch as it then becomes necessary, if he wants to continue his connection with the Society, to go through the grade of Associate Member. I think, however, that this matter would be entirely

in the hands of the Board of Direction. We would simply get more applications from people who wanted to transfer from the grade of Junior to the grade of Member, because they would become eligible, because a man is eligible when he is thirty for the highest grade, but under this amendment perhaps the same thing would not obtain, because no man applies for any specific grade of membership. I merely make that as a suggestion.

THE PRESIDENT.—Any further discussion? The question is on the substitution, in Section 6, of Article II, of the words "thirty-two" for "thirty."

The motion, being put, was carried.

THE SECRETARY.—If there is no further discussion of this amendment, I have a communication from Mr. Samuel Whinery. Letter from S. Whinery.

"NEW YORK, May 29, 1903.

"MR. CHAS. WARREN HUNT,
"*Secretary, Am. Soc. C. E.*,
"220 West 57th St., N. Y.

"DEAR SIR:—As I shall not be able to attend the Asheville Convention, at the business meeting of which the pending amendments to the Constitution of the Society are to be discussed, I ask, if it will be in order, to submit my views on these amendments in writing.

"If I correctly understand the proposed amendments, they will, if adopted, in their present form, change the present practice of the Society in the following particulars:

"1st.—Applications for admission would be simply for membership, and the Board of Directors would determine the class to which the applicant may be admitted. It is not clear, however, from the language of the amendment, that applications for advancement to a higher grade shall be simply for transfer, without reference to grade, since the first sentence of Section 2, Article III, seems to contemplate that applications may be made to the Board for transfer from one grade to another stated grade. The logical inference from the trend of the amendments is that beyond an application simply for transfer, the grade to which the applicant is to be transferred shall be determined by the Board. Indeed, if the general spirit of the proposed change is adhered to, the logical conclusion would be that the initiative in proposing transfers should be taken by the Board, and should not originate in a request by the applicant. There would obviously be serious objections to this principle in practice, since the Board would then be charged with following the professional career of each member in any class in order to propose deserved promotions. While the Board should undoubtedly have the right, after proper investigation, to classify applicants for either admission or transfer, there seems to me to be no sufficient reason why applications should not, as now, be made for admission or transfer to a definite grade.

"The only objection to the present practice that seems to have any weight is that it may be personally embarrassing to the applicant, after having applied for membership in any stated grade, to be consigned to a different and perhaps lower grade by the Board. I think the importance of this objection has been greatly exaggerated. If, however, any applicant is sensitive on that point, there is now nothing to prevent him from applying for admission or transfer to 'Any grade

Discussion on Amendment (continued).

the Board may elect,' instead of naming the grade to which he aspires. In favor of the present practice it may be said that while the Constitution attempts to define the qualifications necessary for admittance to each grade, the question whether an applicant meets these qualifications is an open one, which each corporate member has the right to decide for himself, and to vote accordingly, whatever may be the judgment of the Board. A member may have perfectly valid reasons for voting for the admission of an applicant to one grade and for voting against his admission to another. Furthermore, these reasons may be such that if the grade applied for is stated in the 'blue list' a member may write to the Board giving reasons why the applicant should not be admitted to that grade, while if the grade is not stated in the 'blue list' he may neglect to communicate with the Board under the impression that that body will classify the applicant in accordance with his (the member's), views, and if, when the ballot is issued, he finds that the applicant has been classed in a higher grade than seems proper, he may feel compelled to cast a negative ballot, not because of any objections to the applicant himself, but because he has been placed, by the Board, in a class to which, in the opinion of the voter, the applicant is not entitled. If rejected for such reasons alone, the applicant might have greater cause for dissatisfaction and embarrassment than if the grade he aspires to, after being published in the 'blue list' were changed by the Board before the ballot were sent out.

"2nd.—The number of ballots necessary to reject an applicant would be twenty or more instead of seven or more, as at present. I favor an increase of the number of negative ballots required to reject, and with the present number of corporate members, twenty is not unreasonable, though in my opinion that number is rather too high. Since, however, the membership is rapidly increasing, this number of adverse votes may, before very long, be relatively smaller than seven when the Constitution was adopted, or than it is even now. I think the number of negative ballots necessary to reject should bear some definite ratio to the number of corporate members. A satisfactory ratio once adopted, it would not then be necessary to again change the Constitution with the growth of the Society. If the ratio were fixed at three-quarters of one per cent. of the corporate membership, the number of negative votes required at the present time would be seventeen which seems to me to be about right.

"The proposed amendments are silent upon the question whether a rejected candidate may subsequently renew his application for membership. In view of the probable abolition of the present provisions for reconsideration I think provision for renewal of application should be made, particularly since if not defined in the Constitution, the question of the legality of such renewal of applications is quite sure to arise in the future.

"3rd.—The provision for reconsideration of the ballot upon rejected applications would be abolished. There seems to be wide dissatisfaction in the Society with the existing "Pink ballot" system and it is probably advisable to abandon it; though such abandonment may sometimes result in grave injustice to worthy members of the profession.

"4th.—After admission to any grade of membership the Board would have the power to transfer the persons so admitted to higher grades of membership without the formality of a ballot by the corporate members. In other words, a person admitted to Junior mem-

bership might be advanced successively to the grade of Honorary Member without giving the corporate membership an opportunity to vote upon the question.

"It may readily occur that the desirability of submitting an application for advancement to a ballot of the membership may be greater than upon the original application for admission. Corporate members who voted for the admission of an applicant as Junior may have good reasons to vote against the advancement of that Junior to full membership, and they should not be deprived of the right to do so. If a ballot upon admission is desirable or important at all, it must become more desirable and important in the case of proposed advancement to the grades of Associate Member and Member. I am opposed to this feature of the proposed amendment.

"5th.—Under the proposed amendment applications for admission to the grade of Junior would be treated precisely as are applications for admission to the higher grades, including the ballot by the corporate members.

"Inasmuch as the grade of Junior is a temporary one, membership in which expires by limitation at the age of thirty, I can see no necessity for the proposed change. It seems desirable, for the encouragement and help of the young members of the profession, to allow them to enter the Society in the grade of Junior with as little formality as possible. The question of professional standing or conduct generally does not exist or it is not important. If the applicant possesses the constitutional requirements for admission, and no evidence is presented derogatory to his personal character, there seems no good reason why the Board should not admit him without the formality of a membership ballot.

"For the reasons stated, I would, if present at the Convention, move that the proposed amendments be amended as follows:

"1st.—Strike out Section 3 of Article III and substitute therefor the following:

"3. At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all applications received for admission, or for transfer from one grade to another, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries if deemed expedient; and may, for reasons deemed sufficient, reject the application. If not rejected, the Board shall determine the grade of membership to which the applicant is entitled, and, with his consent, may, except in the case of applications for Junior, direct a ballot.

"2nd.—Strike out the last paragraph of Section 3, Article III, reading as follows: 'The Board shall have power to transfer persons from a lower to a higher grade of membership, and shall notify the membership of its action.'

"3rd.—In Section 4, Article III, strike out the sentence, 'Twenty or more negative votes shall exclude from election,' and substitute therefor the sentence, 'If upon such ballot the number of negative votes, in the case of an applicant, shall exceed three-fourths of one per cent., excluding fractions, of the total number of corporate members of the

Discussion on Amendment (continued).

Society, as shown by the Secretary's report at the last preceding Annual Meeting, such applicant shall fail of election.'

"4th.—Add to the end of Section 4, Article III, the following: 'The Board of Direction, after making such inquiries as it may deem necessary, shall have the power to elect applicants to the grade of Junior; and shall notify the membership of such election.'

"'A rejected applicant may renew his application for membership at any time after the expiration of one year from the date of the ballot rejecting his previous application.'

"If the amendment, so amended, were adopted, the resulting changes in the present practice of the Society would be as follows:

"Applicants for admission to the Society would be classified by the Board; applications for admission to all grades except that of Junior, and for transfer from one grade to another would be submitted to ballot by the membership; the number of negative ballots necessary to reject an applicant would be largely increased and fixed at a definite ratio to the corporate membership; rejected applications might be renewed after one year, and the 'Pink ballot' system would be abolished.

"Yours very truly,

"S. WHINERY."

It seems to me that the suggestion of Mr. Whinery, that a rejected applicant may renew his application for membership at any time after the expiration of one year from the date of the ballot rejecting his previous application is a very wise one, and it is practically what is done now.

Mr. SEAMAN.—I will second that portion, providing that it may be renewed at the end of one year.

THE SECRETARY.—It may be placed at the end of Section 4 of Article III:

"A rejected applicant may renew his application for membership at any time after the expiration of one year from the date of the ballot rejecting his previous application."

THE PRESIDENT.—Is there any amendment to the amendment as read? It has been seconded and it is before the Convention. Is there any discussion?

G. S. DAVISON, M. Am. Soc. C. E.—Mr. President, I should think that the absence of that condition in the Constitution would be just the same as the addition to it. I should think that after a man is rejected, there is no record made of it, and he is privileged to come before the Society at any time. The only difference would be that he might come before the year is out. It is not very likely that the Board of Direction, having had charge of a man's candidacy once, would take it up again within the same year.

THE SECRETARY.—I think I might answer that objection by saying that all applications which come in must go out on the blue list before they come to the Board of Direction at all, so that in case it were not definitely fixed that a certain time should elapse after the original ballot, a man might send in an application once every three months,

and if the usual routine were carried out, his name would go out on a blue list each time as a candidate before it would come to the attention of the Board.

Mr. DAVISON.—I can see the force of the argument, and I think the suggestion is a very good one.

THE PRESIDENT.—Is there any further discussion?

RUDOLPH P. MILLER, Assoc. M. Am. Soc. C. E.—Mr. President, according to this proposed amendment, it seems that the Board does not have to notify the membership of the request for a transfer from a lower to a higher grade. It seems to me that the members ought to have some right to speak on such a matter. There is as much reason why a member should be privileged to express his reasons why a man should not be transferred in the case of a transfer as in the case of an application for membership.

THE SECRETARY.—May I make another explanation? Section 3 of Article III provides that:

"At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for membership in any grade or for transfer from one grade to another."

B. M. HARROD, Past-President, Am. Soc. C. E.—Does the amendment by Mr. Whinery determine the question whether a transfer shall be made by application or by immediate action of the Board? I think that point ought to be settled.

THE PRESIDENT.—The Chair would suggest that it might be well to pass upon the question of the renewal of an application before taking up another subject. Is there any discussion on the motion providing for the period of one year elapsing on the rejection of an application before it can be renewed?

There being no further discussion, the question was put and carried.

MR. HARROD.—I think it ought to be settled whether a transfer is to be made by application from the member or by the immediate action of the Board of Direction.

THE SECRETARY.—Section 2 of Article III, as amended, provides that:

"An application for admission to the Society or for transfer from one grade to another shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected."

MR. HARROD.—Do you think that is a sufficient notice to members; that if they desire a transfer, they may make application themselves?

THE SECRETARY.—Yes, that seems to cover the point.

THE PRESIDENT.—Does any member desire to offer any further amendments to the amendment? If not, the Chair will declare the dis-

Discussion on Amendment (continued).

cussion on the proposed amendment closed, and it will go out to the membership on the letter-ballot in the usual way.

Project for Joint Engineering Building.

The next topic before the Convention is the proposed co-operation of the Society with other National Societies and the Engineers' Club of New York in the erection of an Engineering Building. The Secretary will read a statement covering the history of the proposition up to this time.

THE SECRETARY.—A brief outline of the inception and history of the project to date is as follows: After a preliminary meeting with Mr. Andrew Carnegie, Mr. Charles F. Scott and Mr. Calvin W. Rice, of the Electrical Engineers, called a meeting of some members of each of the Societies, and of the Engineers' Club, on February 11th, 1903. This meeting resulted in the appointment of a Committee consisting of Messrs. Scott and Rice of the Electrical Society, Messrs. Redding, Kafer and Thomson of the Engineers' Club, the latter also a member of this Society, and Mr. John Fritz, and this Committee had a conference with Mr. Carnegie on February 14th, 1903. At this time the Engineers' Realty Company had secured a 50-ft. lot on West Fortieth Street. At this conference Mr. Carnegie wrote the following letter:

Letter from A. Carnegie, Esq.

"2 EAST 91ST STREET,
"NEW YORK, FEBRUARY 14TH, 1903.

"Gentlemen of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Mining Engineers, American Institute of Electrical Engineers, and the Engineers' Club:

"It will give me great pleasure to give, say, one million dollars to erect a Suitable Union Building for you all, as the same may be needed.

"With best wishes,
"Truly yours,
"ANDREW CARNEGIE."

After several subsequent meetings of those who were identified with the project, the various societies appointed each a committee of three to formulate a scheme for presentation to the societies for action. (The Committee of this Society could not be legally appointed prior to the first conference meeting, and the President was requested by an informal meeting of members of the Board of Direction to appoint such a Committee.)

Resolutions of May 15th, 1903.

The resulting resolutions, passed at a joint conference, May 15th, 1903, were presented to the Board of Direction at its regular meeting, June 2d, 1903, and action taken which was in harmony with the recommendations of its Committee.

"1. *Resolved*, that this Joint Conference Committee recommend to the respective governing bodies represented at this conference, that the following resolutions be brought before the several organizations, to be acted on:

"2. *Resolved*, that (*insert name of organization*) unite with (*insert the names of the other four organizations*) or any of them, for the pur-

pose of accepting the sum of $1 000 000 as a gift from Mr. Andrew Carnegie, for the purpose of erecting suitable buildings for occupancy by various societies of engineers and The Engineers' Club, on the sites secured for the purpose on the north side of Thirty-ninth Street and south side of Fortieth Street west of Fifth Avenue, in the City of New York, in the State of New York.

"3. *And resolved further*, that (*insert name of organization*) has a very high appreciation of this generous gift of Mr. Andrew Carnegie, and this additional evidence of his recognition of the engineering profession and his deep interest in the welfare of the national societies of engineers and The Engineers' Club.

"4. *And resolved further*, that a site on the north side of Thirty-ninth Street shall be purchased and held by trustees, or otherwise as shall be determined by the joint committee hereinafter mentioned for The American Society of Civil Engineers, The American Society of Mechanical Engineers, The American Institute of Electrical Engineers, and the American Institute of Mining Engineers, or by such of them as shall vote in favor of coming into this enterprise.

"5. *And resolved further*, that a joint committee shall be created, to be composed of three members of each organization, that shall unite in accepting said gift of $1 000 000 from Mr. Andrew Carnegie; and that the governing body of (*insert name of organization*) shall elect three members of this organization to represent it on and be members of such joint committee; and that the governing body of (*insert name of organization*) shall have the right and power to remove any member of such joint committee who shall be elected by it and to elect any member of this organization to fill any vacancy that shall occur in such joint committee by reason of the death, resignation, refusal to act or removal of any member who shall have been elected by the governing body of this organization as a member of such joint committee.

"6. *And resolved further*, that the character and internal arrangement of the building to be erected on the site on Thirty-ninth Street shall be determined upon by the affirmative vote of at least two-thirds of all of such of the members of said joint committee as shall represent all of the organizations, other than The Engineers' Club, on such joint committee; and that the character and internal arrangement of the club building to be erected on the site on Fortieth Street shall be determined upon by the affirmative vote of all of the three members of such joint committee who shall represent The Engineers' Club on such joint committee.

"7. *And resolved further*, that said joint committee shall, by the affirmative vote of at least two-thirds of all the members thereof, select and employ an architect to prepare the plans and specifications for the building to be erected on the site on Thirty-ninth Street, and for the club building to be erected on the site on Fortieth Street; and shall also obtain proposals for the erection of both of such buildings; and shall have power to make and enter into such contract or contracts as shall be approved and authorized by the affirmative vote of at least two-thirds of all the members of said joint committee, for the erection of both of such buildings; and shall have charge of the erection of both of such buildings.

"8. *And resolved further*, that said joint committee shall continue in existence until all of the purpose set forth in these resolutions shall have been fully accomplished."

Resolutions of the Board of Direction.

The Board's resolutions were as follows:

"*Whereas*, the resolutions submitted by the Joint Conference Committee in the matter of the Proposed Union Engineering Building are not in suitable form, in the opinion of the Board of Direction of the American Society of Civil Engineers, to be submitted to the Society;

"*Resolved*, That it is the sense of this Board that the proposition, when submitted to the Society, should make definite provision for the accommodations necessary for the present and future needs of the several organizations, and that the proportion of the total expense to be borne by each of the organizations concerned should be definitely stated, and be it further

"*Resolved*, That the Board of Direction recommends, to the Business Meeting to be held at the Annual Convention, the adoption of the following resolutions:

"*Resolved*, That the Board of Direction be authorized to ascertain whether suitable accommodations can be obtained for the Society in the proposed new building, with provisions for future needs.

"*Resolved*, That the Board of Direction be authorized to co-operate to this end with the other organizations concerned.

"*Resolved*, that the Board of Direction be requested, provided it is satisfied that suitable accommodations can be obtained, to send to the members of the Society a letter-ballot by means of which a direct expression of the wishes of the Society in the matter may be secured, and to accompany such ballot by a statement of reasons for and against uniting in the scheme with the other organizations.

"*Resolved*, that the Board of Direction, in case a majority of the members, as shown by letter-ballot, are in favor of uniting with the other organizations, is authorized to proceed in behalf of the Society in carrying out the project."

THE PRESIDENT.—The Chair would suggest that in order to bring the resolutions recommended by the Board before the Convention, their adoption might be moved by some member and then the matter will be before the members for discussion.

G. W. CATT, M. Am. Soc. C. E.—To bring the resolutions before the Society, I move their adoption.

The motion was duly seconded.

THE PRESIDENT.—The question is now before the meeting for discussion.

J. F. WALLACE, Past-President, Am. Soc. C. E.—Mr. President, and Gentlemen of the Society: It is a very embarrassing thing, sometimes, to decline a gift, and it is frequently more embarrassing to accept it. When that gift, however, is coupled with conditions, and particularly when those conditions are complex and not easily understood, we may be pardoned for hesitating and giving it a great deal of careful consideration before we give our full acceptance. The passage of this resolution, as I understand the tenor of it, simply

states the case and would put it before the Society for action when it is voted on. Am I right? The refusal to pass the resolution simply places us in a position where, under certain conditions, an answer should be returned to Mr. Carnegie.

The situation, however, is peculiar, in one way, and that is, I do not think, or at least if I am mistaken I beg to be corrected, I have failed yet to see or hear any formal proposition from Mr. Carnegie actually making this offer, as I understand it. Is there an offer of that kind, Mr. President, before the Society? Has there been a formal tender of this amount to the American Society for this purpose?

THE PRESIDENT.—The tender was made in a letter addressed by Mr. Carnegie to the several Societies, the four National Engineering Societies and the Engineers' Club. The original of that letter has never been presented to the Board. It has never been presented, I think, to the Boards of any of the Societies. It is a paper that is not desirable to carry around, but the Chair would state that he has seen the letter, and it is a *bona fide* offer, with Mr. Carnegie's signature attached, as the Secretary has read.

MR. WALLACE.—That being the case, of course, it devolves upon us, as a matter of courtesy, to return some answer, and the question we have to face for the Society is what that answer shall be.

As I said before, the passage of this resolution would bring it before the members of the Society for a letter-ballot. The failure to pass the resolutions will bring the matter before the Society as to what answer should be returned.

The general question embraces two elements for our consideration; one, a professional one, and the other, one of expediency. From the professional standpoint we should not forget that the American Society of Civil Engineers is not a technical society. It is a professional institution. We, and those who have preceded us, have been working together for fifty-one years to build up an institution which shall show to the world the progress of the civil engineering profession in America. The Society has a prestige and it represents the best engineers in America. The profession of civil engineering embraces all the technical engineering branches; it embraces all the specialties; and we should bear in mind that it has been our effort to work to the end that it might do so.

We should also bear in mind that we should not be placed in the position of being the remnant of that profession, or what is left after the profession is subdivided into the several specialties which have sprung up, in our country and among the members of our profession, in the last twenty-five years. (Applause.) We should not forget that our Society stands for something, and it stands for the united efforts

Discussion on Joint Engineering Building (continued).

of its members for half a century. We should not, for a mess of pottage, trade that prestige off or do anything that would in any way take away from it. (Applause.)

I speak rather strongly on that subject, because I have always been a non-resident member, and the Society appeals to a non-resident member in two ways; one, as a source of communication with other members of the Society, as a source of information through the papers and publications, and the other through that spirit that brings professional men together, the prestige of the Society, and the feeling of that connection, the feeling that you are a member of the American Society of Civil Engineers that goes with the man that is isolated on the frontier, and helps him to do his work, and helps him to do his duty, and helps him to maintain his integrity, and causes the sun to be less hot, the rain to be less wet, and the air to be less cold when he has difficult physical tasks to perform, and causes him to maintain his integrity alone and without the support of his fellows. There is a bond there, and we do not want to do anything to lower the standards that we have set up.

From the standpoint of expediency, the American Society of Civil Engineers is to-day on a firm financial basis. We have property worth over $200 000, for which we are under no obligations to anyone. We have a small debt, but the surplus which can be set aside from our dues is perfectly able to take care of that. In other words, in a few years we will be debt-free, and we will even have to hunt some source of expenditure to properly spend the money that comes to us from the dues of the members in a legitimate way. We have ample accommodations. We do not need any more accommodations. Our house is located satisfactorily, and the question naturally comes, from the point of expediency, why should we change? We certainly should not unless there is a great preponderance of reasons for our doing so.

The main reason advanced, or we should presume it to be, is to centralize the engineering societies and the engineering interests.

I dislike very much to speak plainly, because I am a member of the Engineers' Club, and I have friends in the other engineering organizations, and I do not wish to belittle their efforts, or to say anything to which they may take exception, but, in the first place, to look at it from simply the commercial standpoint. There is land to buy, which, I understand, will cost in the neighborhood of $500 000—is that right, Mr. President?

THE PRESIDENT.—That is about right.

MR. WALLACE.—Yes, about half a million dollars, of which we will be expected to contribute either one-quarter or one-fifth, depending upon how many associations go into it. After the land is purchased, as I understand the proposition, there is to be a million-dollar building erected thereon. As I understand the situation, however, the

first part of that money is to be used to provide quarters for an engineers' club, which is practically an engineers' club in name only. (Applause.) I understand that hardly half the members are engineers in the sense that they are even members of the technical societies. It is an institution that is social and largely, or very largely, commercial. (Applause.) There will be left for this Union Engineering Building the residue after the quarters of this social and commercial association are provided. Dividing that space or those quarters by four, as I understand it, we will be in possession of less cubic feet of building for our accommodation than we now have in our present location. We will only have one-quarter of a voice in the management of that building. We contribute a library. The assembly room and all the general facilities of that building are open to a membership that will probably be, in a few years, from 12 000 to 15 000 people, scattered all over this country. We, of course, will have our meetings exclusively. We will still be the American Society of Civil Engineers, but it seems to me that an affiliation of that kind rubs something off the bloom of the peach (applause), or, at least, that is the way it appeals to a non-resident member, in the West.

Looking it over, looking all sides of it over, there does not seem to be any proper reason why the American Society of Civil Engineers should go in and share and share alike with the other organizations that are interested in this matter. I can see plainly why it would be a very desirable thing for the Engineers' Club; I can see plainly why it would be a very desirable thing for the Mechanical Engineers, or for the Electrical Engineers, or for the Mining Engineers, provided they desired it, or for all of them combined, to have the lump leavened with the American Society of Civil Engineers. I cannot see why the American Society of Civil Engineers should leaven the lump.

If it is desired to ask for our co-operation, instead of our affiliation, that is another matter. If we could contribute, or obligate ourselves for some sum toward this building, say $50 000, if you please, or any moderate sum that we could raise ourselves, and help these gentlemen bring about a union building, and have our sub-quarters in it, if you please, and help them in every way, I would be most heartily in favor of it; but I think we lose something in dignity, we lose something in professional prestige, and we will surely lose something in our ability to control our own affairs, and the room in which we live, and the house in which we live, if we enter into a close affiliation of the kind set forth in these resolutions and provided for in this proposition. (Applause.)

George H. Pegram, M. Am. Soc. C. E.—Mr. President, and Gentlemen: There seems to be a good deal of misconception as to what the conditions are under which we are asked to accept this proposition. Mr. Carnegie has apparently provided no conditions except that the participating bodies shall procure the land.

Discussion on Joint Engineering Building (continued).

Some suggestions have been made as to how the libraries should be treated, that is, that they might be put in adjoining rooms, but still there are no conditions as to that. There is nothing in the way of each organization owning and keeping its library intact, as it does now. In fact, the only proposition now is the joint tenancy of that building. There is no question of affiliation involved. The other societies, that is, the Mining Engineers, the Mechanical Engineers and the Electrical Engineers have practically adopted those resolutions that were originally presented to our Board of Direction and were rejected by our Board as not suitable in their present shape to present to the Society. These three societies have practically accepted them and appointed the joint committee that is to confer and to direct the execution of the project. The Engineers' Club was to have acted last night, and probably did so, as they practically drew up the resolutions and have been in favor of them all along.

That, then, leaves it with the four organizations, that is, all the organizations except the American Society of Civil Engineers, with their permanent committees appointed. All along they have assured us that whether we came in or not, it made no difference to the carrying out of the project. A Committee, really of information, was appointed at an informal meeting of the Board of Direction, when the matter was first brought to our notice, and they directed the President to appoint two members to act with himself. The President appointed Mr. Wilgus and Mr. Freeman, but Mr. Freeman, being a member of the Board of Direction of one of the other societies, declined, and I was appointed in his place.

Mr. Freeman, at that meeting represented, probably as Mr. Wallace has, the sentiment of his locality, and we were rather surprised to find such a unanimous sentiment in Boston, because in New York we felt that everybody was pretty much at sea. Apparently, none of the Boston people are here—I don't know whether they are here or not—but Professor Swain, who was present at the meeting of the Board of Direction which adopted these resolutions that have been presented to-day, has sent a letter to our Committee giving the sentiment of the Boston members as far as they could determine it, and in his absence I think it would be proper to read that letter here if there is no objection, Mr. President.

Letter from Geo. F. Swain.

This is from Professor Swain, and it relates to a telegram that was sent to him at New York from Boston, while he was in attendance upon one of our Board of Direction meetings. It says:

"Boston, Mass., June 4, 1903.

"Mr. Alfred Noble,
"20 West 34th St.,
"New York, N. Y.

"My dear Mr. Noble: I am very sorry that the telegram which was sent me from Boston, containing the result of a canvass of the members there with reference to the Carnegie proposition, was not de-

livered to me Tuesday evening. You will be interested in its contents, which were as follows:

" ' Result of ballot of acceptance, Carnegie offer,
' In favor, 47;
' In favor with present information, 33;
' Non-committal, 7;
' Opposed with present information, 7;
' Opposed, 9.

' S. E. TINKHAM.'

" This is a result which is a little surprising to me and is very satisfactory; and I think it shows one thing quite conclusively, and that is that the Society should pass the resolutions which we voted Tuesday evening to recommend to the meeting at Asheville. I think likely some of the members who are opposed to the plan would like to reject it entirely and have nothing whatever to do with it. I sincerely hope, however, that the Society will have more discretion. Personally, I thoroughly believe in the scheme in principle, but of course the practical details must be worked out before we can definitely enter into it. Personally, also, I believe that these details can be worked out. I think the spirit in which we should approach it is an earnest spirit of appreciation and a sincere desire to make the scheme a success, and that, if we approach it in this way, we can make it a success. On the other hand, if we start in with the hope and the desire to pick flaws and to defeat the scheme, we might be able to do so.

"I thought you might be interested in this result showing the feelings of the Boston members, and I send it to you for the reason that I cannot go to Asheville, and I thought it might be of some use to you if necessary to persuade the Society to take the initial steps and pass our resolutions. I am sending a copy of this letter to the other two members of your Committee.

" Very sincerely yours,
" GEO. F. SWAIN."

I would say in explaining those resolutions which were offered, that the Board of Direction, or rather the Committee appointed by the Board, asked the opinion of counsel as to the legal procedure and as to certain questions about which we were in doubt; for instance, whether, if we accepted and became one of the proprietary bodies and had a joint committee in which we would always be in a minority, we might, if such a condition became distasteful, withdraw, without the loss of what we had put in. The opinion of counsel and answers to those questions, and also with reference to these resolutions, I probably had better read, Mr. President. This was obtained for information only; in fact, our Committee has been simply one of information. This is addressed to Mr. Alfred Noble, President.

Letter from Counsel.

" NEW YORK, June 2, 1903.

" ALFRED NOBLE, Esq.,
" 20 West Thirty-fourth Street.
" New York City.

" DEAR SIR: In the matter of the proposition of Mr. Andrew Carnegie to erect a union engineering building, you ask me as to the effect

Discussion on Joint Engineering Building (continued).

of resolutions of substantially the following purport, if adopted by the American Society of Civil Engineers at its general business meeting:

"(1) A resolution authorizing the Board of Direction to ascertain whether suitable accommodations can be obtained for the Society in the proposed new building, with provision for future needs.

"(2) A resolution authorizing the Board of Direction to co-operate to this end with the other Societies.

"(3) A resolution requesting the Board, provided it is satisfied that suitable accommodations can be obtained, to send to the members of the Society a letter-ballot regarding the proposed new building, accompanied by a statement of reasons for and against uniting in the scheme with the other Societies.

"(4) A resolution directing the Board, in case a majority of the members, as shown by letter-ballot, favor the project of erecting the new building, to proceed with the other Societies in the erection of the building.

"I have no hesitation in saying that such resolutions so adopted would be in harmony with the Constitution of the Society and that the Board of Direction would, upon the adoption of the resolutions, be legally warranted in acting in conformity with the resolutions.

"You ask what would be the situation if one of the other Societies mortgaged its interest in the new building and defaulted in payment under the mortgage.

"You also ask me what would be the situation in case of the withdrawal of one Society.

"I venture the suggestion that an agreement can doubtless be framed covering the foregoing points, with such others as may occur, in a way to safeguard the Society's property interests provided the Carnegie proposition is accepted.

"It would be not only the right, but the imperative duty, of the Board of Direction to insist upon the execution by the other Societies of instruments necessary to protect the American Society of Civil Engineers, as a condition precedent to committing that Society to a fixed plan.

"Yours truly,

"HERBERT E. KINNEY."

There are some other communications, Mr. President, which have come to our Committee, if it is proper to read them.

THE PRESIDENT.—You may read them.

MR. PEGRAM.—Here is a telegram received from New York, addressed to Mr. Noble:

Telegram from several Members.

"We, the undersigned, members of the American Society of Civil Engineers, without now expressing our preference for or against the Society's participation in the gift of Mr. Andrew Carnegie, to the cause of engineering, most respectfully recommend their fellow members, assembled at one of its regular general business meetings, that the question be submitted to the entire membership by letter-ballot without unnecessary delay, as such action, in our opinion, and according to competent legal advice is fully warranted under our Constitution; and, moreover, it is the individual right of every member to have the opportunity to vote on so important a matter.

"HENRY G. PROUT, CHARLES MACDONALD, S. WHINERY, JOHN FRITZ, O. F. NICHOLS, D. L. HOUGH, JOHN BOGART, W. E. BAKER, JOHN F.

O'Rourke, George W. Melville, A. Mackenzie, George A. Just, Foster Crowell, W. L. Saunders, M. Lewinson, Robert B. Stanton, D. McN. Stauffer, L. L. Buck, E. E. Olcott, Emil Kuichling, E. G. Spilsbury, J. Waldo Smith, Bernard R. Green, John Thomson, A. P. Boller, H. W. Hodge, Geo. W. McNulty and William Metcalf."

Charles Hansel, M. Am. Soc. C. E.—Do you offer this as a resolution?

Mr. Pegram.—No, this is simply information that has come to the Committee from members who cannot be present.

Mr. Hansel.—I understand they asked that it be offered as a resolution.

Mr. Pegram.—Well, the course outlined in the resolutions before you is to this same end, that the matter be decided by letter-ballot.

Mr. Green.—Mr. President, my name is attached to this telegram, and I wish to explain that I gave a very hasty answer, yesterday afternoon before leaving Washington, to a telephonic communication which did not give me quite all the information that is contained in that telegram. I am willing to vote for the letter-ballot in proper time, but not immediately, and therefore, as the thing now reads, I would rather my name should be withdrawn from among the signatures.

The Secretary.—I have two letters that were addressed to the Board of Direction, one from Past-President A. Fteley, and one from Mr. E. L. Corthell.

Letter from A. Fteley.

"May 31st, 1903.

"To the Board of Direction of the Am. Soc. C. E.

"Sirs. Allow me to contribute a few words, as a member of the Board of Direction, to the discussion of the Carnegie proposition which is to take place at your next meeting.

"The perusal of the pamphlet sent me by President Noble suggests the thought that the whole matter was started and prepared, almost entirely, without consultation with any authorized member of our Society; probably in the expectation that the glamour of the munificent offer made could prevent all possible opposition, if any were intended.

"That other bodies, differently situated in material prosperity or otherwise, think it out of the question to refuse the offer made, I easily conceive, and, from the statements made to him, Mr. Carnegie probably received the same impression.

"I feel confident, however, that it would be against the best interest of our Society to follow the others in the acceptance of the pending proposition. We have worked many years to build up our organization and we have now reached, professionally, financially and materially, a desirable position with which we should be satisfied. To now partially lose our distinct identity and to unite with other bodies, some of which have not the same aims as ourselves, would be of no advantage to us and might be of detriment.

"I fail especially to see the propriety of uniting with the Engineering Club. Admirable as it may be in its own sphere, its aims

Discussion on Joint Engineering Building (continued).

and methods are obviously different from ours; it is not a professional organization, and, as it would actively occupy its part of the proposed building every day in the year, it would obviously appear to outsiders to be a representative body and would give to the whole a social and festive character which we do not care to assume. Many of its members, I understand, are commercial representatives of firms, the sale of whose goods and products are controlled by Engineers, and an apparently close association would hardly be consistent with the 'maintenance of a high professional standard' mentioned in our Constitution as one of the main objects of our Society.

"The whole subject has been treated with undue haste. In the pamphlet sent me by the President, and in the press references which have reached me, I have not seen a word in regard to the financial management of the proposed building. The equipment and maintenance of such a large establishment is very expensive, and, from what I know of the financial resources of the bodies invited to join the Union, they would have to increase substantially their annual outlay in order to meet the expense of the annual maintenance and the gradual extinction of the debt contracted for the purchase of the land.

"A number of financial and legal questions connected with the joint ownership and management of the property would necessarily arise and should be inquired into before launching into such a radical change as is now proposed. Competent legal opinion alone can define the legal status of the various members of the joint ownership.

"With hopes that the call of the Board for an expression of opinion by the members of our Society will be accompanied by such a sober and judicial statement as will convince them that it is for our own best interest to retain in full our present identity, and counteract any contrary argument that may be sent independently to them, I remain,

"Yours respectfully,
"A. Fteley,
"M. Am. Soc. C. E."

Letter from E. L. Corthell.

"Great Barrington, Mass., May 29, 1903.

"To the Board of Direction,

"*American Society of Civil Engineers,*

"220 West 57th St., N. Y. City.

"Dear Sirs:—I desire to present briefly my views in regard to the proposal to accept from Mr. Carnegie $1 000 000 for the purpose of building a joint house for the National Engineering Societies of this country and for an Engineers' Club.

"As the matter now stands, as it has come to me largely through the public press, I am not in favor of the proposition. I do not think our Society should unite in as intimate relations as are proposed, with the other national societies, for the reason that its standing, its requirements and its purposes are considerably different. I need not go into details in respect to these differences. I cannot better express my own views in regard to these differences than by referring to the presidential address of Mr. George S. Morison delivered on June 19, 1895, and found on page 477 of Volume 33. On that page in two paragraphs he shows clearly the difference and brings out, I think, better

than I can possibly do, the reasons why it would be improper to unite in any close relations societies of such different character. He says:

"'Our Society should include the choicest minds in every branch of engineering; it must have among its members the leading members of every society which represents an engineering specialty. No other society can have our general range; on the other hand, no other national society can make the same restrictions as to individual requirements. Each of the other societies is devoted to some specific branch of engineering, but the individual qualifications should be comparatively light; it receives into its ranks every engineer working in its specialty, as we receive engineers of every specialty, but not every engineer.

"'The American Society of Mechanical Engineers accepts as a member anyone who is 'competent to take responsible charge of work in his department;' it is not necessary that he should be able to design, and while this would be a bad provision for our Society, it is exactly right for the Society of Mechanical Engineers. We take in educated men of every branch of the profession; each other national society takes in every man who is devoted to the specialty which that society represents.'

"These are exactly the relations which exist between the Institution of Civil Engineers of Great Britain and the other societies that have to do with special features of engineering. I cannot conceive of that institution uniting closely with these other societies. I do not believe that any financial temptation—a million or ten million dollars—would be looked upon with favor for a moment by that great Institution, and we are equal to it in every respect so far as requirements for admission, professional standing of the members and other important features which distinguish it from other societies are concerned.

"In 1895, when I endeavored to establish an international institute of engineers and architects, I found that in order to establish any relations at all between the engineers of different societies and of different countries it would be necessary to keep the societies of a high and low grade separate, as they are now, but individual members of these societies could, for the purposes stated in my proposition, be united in an institute, but that it would be necessary to make the requirements for admission as low as possible, and they were to be simply, 'Any person engaged in the profession of engineering or architecture, of mature age and of good character.'

"If it were possible to change the constituent features of the various societies which it is proposed to unite so as to bring them up in requirements, in character, in experience, to the American Society of Civil Engineers, I think the proposition should meet with the approval of our Society, but it is impracticable to change these other societies; consequently we will have to go down to their level, and that we cannot do.

"I hope the views very briefly expressed above and my opinion will be in accord with your own, when the matter has received full study and discussion. I am,

"Yours respectfully,

"E. L. CORTHELL,

"*M. Am. Soc. C. E.*"

MR. CROES.—Mr. President, when this matter was first called to my attention my feeling was one of surprise at the maturity of the

Discussion on Joint Engineering Building (continued).

project, apparently, as presented, without any previous notice having been given to any of the parties concerned. On examination, it appeared that an after-dinner speech by the President of the Electrical Engineers appealed to Mr. Carnegie's feelings, and he sent for Mr. Scott the next day and told him that he would like to aid in erecting a union engineering building for the engineering societies. Mr. Scott called in a very few members of those various societies, and although he was told, and Mr. Carnegie was told, that the American Society of Civil Engineers had, for twenty years, been considering the proposition, and had every time refused to enter into a union building, the majority of the gentlemen consulted thought that the thing might be worked out, and so they had gone to Mr. Carnegie and he, thereupon, wrote a letter which you have heard read, to the four Engineering Societies and the Engineers' Club, a purely social and commercial organization, which was then negotiating for the property on Fortieth street, in New York City. That proposition was held by the gentlemen who received it until a site in immediate proximity to the Engineers' Club could be obtained, or options on it could be obtained, so that it might be purchased and be preserved for the erection of a union building for the five organizations.

The property of the Engineers' Club fronts on Fortieth Street, 50 ft. by 99, and the contiguous property which the engineers are to occupy is on Thirty-ninth Street and is 125 ft. by 99. The two plots are backed up against each other. The union building must run through from street to street, with an entrance on Fortieth Street and an entrance on Thirty-ninth Street.

When this option had been obtained, an announcement was made, on May 3d, that such a project was under way. A meeting was called of all the directors of all the various societies concerned, to take place three days later, on the 7th of May; the time was fixed; the place was fixed—the house of the American Society of Civil Engineers. The American Society of Civil Engineers did not know anything about it. On the 5th of May the Board of Direction of the American Society of Civil Engineers met and, finding that a meeting had been called, agreed to invite the gentlemen to attend it, and requested that some members of the Board of Direction attend the meeting to see what was going on. They did so. They found that on three days' notice the Board of Direction was called upon to adopt a set of resolutions carefully prepared, stating that the American Society of Civil Engineers and the other societies, officially assembled, accepted the proposition of Mr. Carnegie, and they also had a cablegram prepared, which was to be forwarded to Mr. Carnegie, that the members of these societies, officially assembled, accepted his offer with thanks.

Some of the members of our Society and members of the Board of Direction were present, and as those resolutions and that cablegram

were entirely untrue, they succeeded in securing the substitution of a resolution thanking Mr. Carnegie.

Now, the proposition which was submitted at that time and presented to that meeting and made public, as I said, three days before, was an elaborate scheme drawn up by a lawyer for the management of the whole thing, and providing for the election of trustees who were to be, I believe, perpetual—at any rate they were practically self-appointed to carry out the whole project.

Without any regard to anything else I will say that that movement was not timely, and one of the greatest philosophers of modern days has said that "our words and actions, to be fair, must be timely." These were not timely. There was not an opportunity given for discussion. Well, that was not passed, of course.

On examination, I found that there were not a dozen members of the American Society of Civil Engineers who knew anything about this, and while there were publications issued, and some of them appeared in the public press, and some pamphlets were sent out, there was not any general information regarding the project which involved the reversal of the policy of the American Society of Civil Engineers from its foundation; and we were told, and it was urgently impressed upon everybody connected with the government of the American Society of Civil Engineers, that it was absolutely necessary that that project should be accepted at once, and certainly within thirty days, because the option on the piece of land which the gentlemen of the Engineers' Club had selected as a good one for the Society house would expire within that time. On inquiry, I found that there was not any such hurry at all; that Mr. Carnegie had said that if any one society did not choose to come into it, that his offer held good for the others; and, as we are not under boss rule, or under clique rule, but are a democracy where every man has a voice in the management of the Society, it was necessary for us to take a popular vote on the subject and to have the approval of all the members.

Well, I thought under those conditions that it would be well to feel the pulse of the men who had taken part in the growth of the Society, men who had built it up and who had held official positions in it and who were more intimate with its affairs than anybody else could be, and so I addressed to a number of them a letter stating somewhat concisely the condition of affairs, reciting in the first place what I have just said to you of the manner in which the proposition was brought about, and then making this proposition:

"It is important that the members of the Society should carefully consider the proposition in all its bearings, and that they should be prepared to uphold the old established policy of the American Society of Civil Engineers unless some very strong argument can be brought forward in support of a reversal of that policy.

Discussion on Joint Engineering Building (continued).

"That policy may, I think, be thus stated: The Society is not an educational institution, nor a commercial exchange, but an association of men who have acquired such an education and practical training in any branch of civil engineering as to warrant their being classed as members of a profession, and not simply as expert mechanics, or skillful tradesmen. Juniors and Associates are affiliated with them, but not on a membership basis, and they have no voice in the management of the Society. The full membership of the Society is intended to carry with it, so far as practicable in any such organization, a guaranty of the mental, moral and practical fitness of a man to be ranked as a professional civil engineer. It is not consistent with the aims and purposes of this Society for it to be associated with other organizations having a lower standard of membership, in such a way as to lead either the members of such organizations or the general public to assume that all the persons so associated stand on the same professional plane.

"It is an indisputable fact that while there are in the various other engineering societies many members who rank as high, professionally, as any members of the American Society of Civil Engineers, and a very considerable number, 250, about, are also members of the latter society, the only reason for the existence of the other societies is that there have been and now are a great many men who feel the need of an Association, but are either unable or unwilling to comply with the requirements of the American Society of Civil Engineers as to full membership and who wish to be members of only such an organization as will accord to them the privileges of the highest grade of membership and participation in the control of the organization."

There always must be a number of societies in the same branch of business, whatever it is, but they are societies of different grades. We have a standard, as Mr. Wallace has well said, which the other societies have not.

"The American Society of Civil Engineers has never been disposed to engage in any business or professional alliance with such societies of such a nature as to lead to a general impression of the equality of the professional standing of all the parties to the alliance. It is now proposed that the American Society of Civil Engineers shall unite with the other technical societies and with also an unprofessional, social and commercial organization in the acceptance of a gift of a building to be occupied by them in common. In the deed of gift all the societies are grouped as co-ordinate and equal. In the scheme of co-operation proposed by the promoters of the project, all the recipients of the gift of the house are designated as tenants in common, share and share alike. The libraries are proposed to be merged in one, and the auditoriums are to be used by all alike. The purchase of the land on which the building is to stand is to be shared in by all.

"Leaving out of view the moral considerations which have heretofore influenced the action of the American Society of Civil Engineers in this matter, and considering only the business features of the proposed arrangements, it appears that, of the five participators in this arrangement, the American Society of Civil Engineers owns and occupies a commodious house, built for its use, which is valued at $250 000, and has on it a mortgage of $55 000, which is being paid off rapidly from current receipts. It also has a library of over 40 000 volumes, valued at $50 000.

"The Mechanical Engineers own property valued at about $80 000.

The Mining Engineers own no property, have a small library and say they don't want a building. The Electrical Engineers own no property, are understood to have a building fund of $30 000, and have begun a library. The Engineers' Club owns no property and has no library worth mentioning.

"It appears, therefore, that the one successful, well-conducted and prosperous organization of the group is asked to go into partnership with four other concerns which have not demonstrated their ability to acquire or manage a large property, in the purchase of three-quarters of a million dollars' worth of land, and in the control and management of the million-dollar house.

"This proposition does not proceed from the party in interest which has now cash and credit, but from some of the others who wish to be associated with that party, and who have, at the outset, attempted to enforce an immediate acceptance, saying 'that the details can be arranged afterward.'

"I believe this is a fair statement of the case as it stands, and I would be glad to know from you whether you think it desirable or consistent with the best interests of the Society to entertain the project of an affiliation with the other societies above named in the manner proposed."

I make that statement to you that you can see precisely whether or not I was fair in the statement. I expressed no opinion in it except what comes by inference. (Laughter.)

Now, looking over the persons to whom to send that, I thought that good men to send it to were the eight survivors of the nineteen men who were elected Members of the Society at its revival in 1867—December 4th, 1867—when the Society was revived after being in a comatose state for some ten or twelve years. There were nineteen men elected, and eight of those still survive. One of them took an active part in the reorganization and in the management of the Society, and has been a director and a Vice-President, and has contributed to the funds of the Society by subscription for the building in Twenty-third Street—and right here I might as well say that the building which we own now was not built by subscription. The building in Twenty-third Street was largely purchased and enlarged from subscriptions obtained from members and from others, but the present building was built by the Society out of its own funds, only $19 243 being contributed by subscription, and it is being paid for out of its own funds (applause); it is not the gift of anybody.

Letter from Thomas Fitch Rowland.

Well, this gentleman I speak of also contributed a fund for founding a prize for the Society, the Rowland Prize, and he is now an Honorary Member of the Society, for I speak of the Hon. Thomas Fitch Rowland, an Honorary Member of the Society; and he wrote in reply a letter which I ask to have incorporated in the minutes of this meeting.

"I had already given the subject upon which you address me, much earnest thought, and have carefully perused your letter, and the printed article, over your signature, copy of which you enclosed.

Discussion on Joint Engineering Building (continued).

"I am firmly of the opinion that it would be a dire calamity to the welfare of The Am. Soc. of C. E., were it to assume any part in the schemes now in vogue, to entice it from its high estate, and signally commanding position of being *the oldest*, most distinguished, and world-wide known Society of Engineers on the Western Hemisphere.

"Were I in proper health, I should most certainly make it my business to visit Asheville, upon the occasion of the coming convention, to do whatever I could, in the way of convincing gentlemen there assembled, that such co-partnership, or 'community of interest,' as has been proposed, would, in my opinion, be fatal to the best interests of our Society, and would be a monumental mistake, that would mark the primal epoch of a departure, from the true line upon which our Society has always traveled, of minding its own affairs, and perhaps might possibly be indicative of the Society's approaching decadence.

"I am unable to travel, and in such indifferent physical condition, as to be debarred from taking active interest in Associations, or other business matters, but I earnestly agree with you, in all your adverse criticisms [Mr. Rowland had also read at that time a letter which I addressed to the public press, in which the same sentiments were expressed, but with an opinion. In writing to the members of the Society, I was careful not to express an opinion. In writing to the Press I was careful to express that opinion as forcibly as I could], and heartily hope The Am. Soc. of C. E., will make no arrangements, to in any way become identified in any co-partnership, or any 'community of interests,' with other Technical Societies.

"Although a third of a century has rolled away, I vividly still remember, the satisfaction and pride with which you and several other gentlemen (who are yet alive) together with myself, accepted invitations, and upon December 4th, 1867, became elected Members of The Am. Soc. of C. E., and ever since, as opportunity has presented, each and all, so far as I can recall to mind, have done whatever they could, to help build up this noble Incorporation, which has long been recognized throughout the business world, as an Engineering Society of the highest type, whose transactions and technical literature, often become consulted by Government Officials, Civic Associations, Capitalists and others, who have been thereby enabled to obtain the best of professional data, and engineering experience of the Society's members.

"In conclusion, I repeat my earnest accord with all of your adverse criticisms. and certainly hope the Society will make no radical change in its status, or general methods of administration, under which it has grown from feeble infancy to its present stalwart proportions."

I place that letter first because it is from an Honorary Member who for thirty five years has taken an active part in the management of the Society, as you know, and because another opinion had been expressed by one of our Honorary Members, Mr. John Fritz. Now, Mr. Fritz, for twenty-five years, while the Society was attaining its present position, never by word or deed gave any aid to the American Society of Civil Engineers, and it was not until ten years ago, after he had passed the allotted life of man and was over seventy years of age, that he applied for membership in the Society. I think that the opinion of that Honorary Member who has taken an active part all the way through is to be preferred to that of one who has taken no part whatever.

I addressed the letter to another one of those eight men, Mr. Charles Paine, a former President of the Society, whom you all know. He replied: Letter from Charles Paine.

"I am of your opinion that the A. S. C. E. should remain free and independent. Its members can enjoy all the advantages of the other societies by simply joining them; and if they wish to lunch at the Club, they will be admitted on the usual terms. The proposal to unite the A. S. C. E. with the other societies could only come from persons who do not conceive the purpose for which the A. S. C. E. was organized. The older members of our Society will know how difficult it has been to maintain the standard of character and to avoid the desire of young (and even of older) members to advertise themselves or their inventions by means of *papers*. Those things are permitted or occur more or less in the proceedings of some of the other Societies; and would affect the estimation in which our Soc. is held, if a near association were established. No scheme for a complete independence of administration has been suggested; if there were such an independence provided for, the A. S. C. E. would have nothing more than it has now, and gain nothing important. The Association for the Advancement of Science, which is every way an important organization, might as well say to the Academy of Sciences, 'let us swallow you, we are more numerous'; or the League of Artists, to the National Academy of Design, 'let us rule your affairs,' as to have the 4 Engr'g associations propose to meddle with the A. S. C. E.

"I am aware that they do not propose this meddling now, except in the joint administration of property; but the same sentiment which makes me prefer to have a separate dwelling for myself makes me prefer a separate home for the A. S. C. E. In my opinion the cause of Engineering as a profession will be served by maintaining the A. S. C. E. independent and free of all entangling alliances."

Another of those first members was Mr. Mendes Cohen, a Past-President of the Society. He writes: Letter from Mendes Cohen.

"Through a personal letter from the editor of one of the technical journals, I learned of the inclusion of the *Engr's' Club* in the scheme. I replied that I could conceive of no possible advantage to the Am. Soc. C. E. of being associated with a social club in a business arrangement of such importance. That on the contrary I saw many and grave objections thereto.

"I had not been well and it did not suit me to prepare my views for publication as I was invited to do, but I am unalterably opposed to such an affiliation, and with that feature fixed as part of the combination I would most strenuously oppose any co-operation in it on the part of our Society.

"I regret that it will not be possible for me to be present at the Convention, where I would be glad to join you in opposing the scheme."

Another was Mr. George S. Greene, Jr., for many years Engineer-in-Chief of the Dock Department of New York City, and a Past Vice-President and Treasurer of the Society, and you may see that the questions on which I asked his opinion are distinctly stated in his preamble. Letter from G. S. Greene, Jr.

"You ask for my opinion in regard to the American Society of Civil

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Engineers joining with three other technical Societies and a social club in the ownership, control and management of a home in this city.

"The American Society of Civil Engineers is the oldest and it is the most dignified of the technical societies considered, in that it has a high standard and requirement of eligibility to full membership, while at the same time it is broad enough to embrace all classes of members that the other societies include.

"It has its own house, under its own control, sufficient for its purposes and capable of enlargement when there is need.

"It has its own library under its own control and management.

"It is not in any pressing need of money.

"It is independent, and the leading society.

"It is proposed that it become one of five in the occupation, control and management of a house and of a library for the sake of the advantage of whatever share of one million of dollars, (less whatever it may have to pay for land), may be allotted to it by the majority vote of four other societies and itself.

"It cannot become one of five without losing its independence, its prestige and its leading position, and thereby decreasing its ability to benefit the profession, and the commonwealth. It would lose much and gain but little if anything consequential.

"Whatever the other societies may do, I hope that the American Society of Civil Engineers will maintain its present position."

Letter from Henry G. Morris.

Another was Mr. Henry G. Morris, of Philadelphia, an engineer, machinist and mechanical engineer. He said:

"I agree with the general terms of your position as to the desirability of entering into a business partnership with other organizations, as has been proposed.

"The action of the Board in appointing a Committee to investigate the proposition, seems to have been well taken, and, of course, as a democracy, the members will bow to the opinion of the majority, when the results are expressed by the ballot.

"If there is any intention of having 'Carnegie blown in the front'—as remarked by Mr. Dooley in his article on Carnegie Libraries—I would certainly strongly object to a combination such as proposed.

"I much regret that I will not be able to be at the Convention at Asheville, but I feel satisfied that the older and conservative members of the Society will be well represented."

Letter from Edward P. North.

Mr. Edward P. North, a Past Vice-President, and one of the original eight, wrote as follows:

"When you honored me with your communication on the affairs of the American Society of Civil Engineers, you knew that for more than 20 years I have advocated making provision in the Society house for the special engineering societies, but without putting in peril our eminently respectable position or capital. The generous offer of Mr. Carnegie may make some combination between the four national technical societies possible in the near future.

"On the other hand, I fully agree with you that allowing a non-technical club to intervene in the affairs of the American Society of Civil Engineers is impossible. And the plan for 'a suitable Union Building for them all' should be so modified that the affairs of the Engineers' Club are permanently segregated from those of the American Society of Civil Engineers. Nor do I fully approve of the pro-

posed proximity of our meeting room with a club house, which, while it may not be injurious to men of mature years and well-established habits, does not seem desirable for those younger men who are just entering their profession and whose attendance at our meetings has so far proved beneficial.

"Writing from my standpoint, as desiring an advantageous arrangement between the four national societies, it seems the first thing is to settle its practicability and then settle the forms and terms of the co-partnership. When planning work for which there is no precedent, all possible difficulties should, as far as possible, be foreseen and provided against, and these provisions should be criticized by one who has not made the plan.

"This proposed partnership involves a problem with which we are all inapt. It is an absolutely new proposition, out of our experience, to be governed by the laws relating to associations, in which laws few or none of us are expert. And safeguarding the rights of the parties to the real estate and the proposed common house standing on it will probably present questions for which there are no legal precedents. It was with these difficulties in view that at the meeting of the 7th inst., to which you refer, I advised that before any of our capital was merged in a common undertaking, a sum at least equal to one year's income on that capital should be expended on legal advice.

"With these views I am obliged to return a qualified answer to your question, viz.: I do not think it is desirable or consistent with the best interests of the American Society of Civil Engineers for it to entertain the project of affiliation with the other societies above named in the manner proposed. But, after the terms of a possible affiliation between the four technical societies have been arranged under competent legal advice, I think the proposition should be submitted to the Society. The project is too important to us, its disadvantages too patent, and its advantages too doubtful for the hurried action wished by some.

"While I am unable to agree fully with all of your views, I think all the members of the Society should read them, and hope the fact that you are a member of the Board will not prevent your asking the Board of Directors to give your communication publicity in the Society."

Letter from Alfred P. Boller.

There is yet another one of those early members who was at one time, for a couple of years, the Secretary of the Society, Mr. Alfred P. Boller. You all know him, and I don't think that any of these men whose letters have been read, while they are old members, can be said to be "veterans who lag superfluous on the stage," because they are all still actively engaged in work. Mr. Boller wrote:

"Answering your favor *in re* the momentous step proposed to the Society looking to a partnership arrangement with its sister Engineering Societies. The subject has been much in my thoughts, and between the conservatism natural to a veteran, and a recognition of progress as a law of healthy development, I find it hard to come to a concrete conclusion. The project has much to commend it, and if wisely carried out, will I think strengthen a public appreciation of the professions on which modern civilization has been built up. Our Society has had a phenomenal career and has been built up on a standard of membership that is unique among Am.

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Societies, and which has put us in the front rank. Further, we have been wisely financed until our resources have become most substantial, and increasing steadily. We ourselves do not need the gift, and will continue to grow as long as the present policy and traditions of the Society are maintained, and the first impulse is to let well enough alone. Is there a broader view and a responsibility to the profession of Engineering as a *whole*, of which we are now practically only a subdivision? I think there is, and am inclined to endorse a great Union Building on certain conditions, having in view our greater financial responsibility, which is fully twice as great as all the other Societies combined.

"1st. Our position as the representative Society of Civil Engineers must be maintained, just as it now is.

"2d. The ground rent (Mt'ge) while probably safe in Carnegie's hands, after he is gone may be a source of future trouble—unless he makes a provision that it shall never be made a danger ground for the 'combination.' If this can be done, it goes a long way toward eliminating the financial inequality and unequal responsibilities of the Societies.

"3d. Absolute separation from the Engineers' Club or any mixture whatever with that Social organization that would group it as one of the 'Engineering Societies.'

"The fund must be absolutely separated, so that the Engineers' Club does what it likes with the part dedicated to its purposes, and and the Engineering Societies with theirs. The buildings must be separate and distinct, and in no way mixed up. The Engineers' Club as such must not be in the Board Trustees or management of the Societies' building. I am strong in my opinions as to this branch of the subject, as the Engineers' Club seems to be very aggressive in instructing the Engineering Societies what they should do, and manifest an expectation of being established as a collateral branch of the Technical Societies. Of course it would be a mighty good thing for the club, but should be guarded against. As a matter of fact I have never been more puzzled as to just what we should do. I hate the thought of giving up our building and separate independence, but the younger men and changed conditions must be fairly considered. But I would make it a '*Sine qua non*' that the conditions of the ground rent should be such that at *no* time could the property be foreclosed, nor the Societies ever be restrained in the full enjoyment of the building, should conditions at any time arise, interfering with the paying of interest either in whole or in part."

Letter from Thomas C. Keefer.

I further sent this letter to the Past-Presidents of the Society who are living, and had not already publicly announced their conclusions, as I thought they were men who ought to know something about it, and have opinions that were worthy of consideration. In reply Mr. Thomas C. Keefer wrote:

"I agree with your view of the position. You have nothing whatever to gain and very much to lose in such a merger. It would be like abandoning a Home for a Hotel.

"There is nothing, not even a Library, that you could afford to hold in common with other independent bodies, as there would be sure to arise dissension out of the joint use of apartments held in common.

"We have succeeded in having 'thrown out' by the Private Bills Committee of Parliament here, a Bill to incorporate a 'Dominion

Institute of *Amalgamated Engineers'* by showing that the Canadian Society provided, as does the American, and the British Institution, for all classes of Civil Engineers."

Letter from Octave Chanute.

Another Past-President, Mr. Octave Chanute, wrote thus:

"My first impression was that the American Society of Civil Engineers might lose so much in disposing of its present building, that it was so well provided for and so well off financially, that it could afford to abstain from participation, and thus allow other Engineering Societies not mentioned, such as the Naval Architects and Marine Engineers, the Military Engineers, the Engineering Education Society, etc., etc., to avail, with the three other National Societies mentioned, of Mr. Carnegie's magnificent gift, for which all members of the Engineering profession must be profoundly thankful.

"My second thought was that the holding aloof by the American Society of Civil Engineers might impair Mr. Carnegie's intentions, and that the first requisite step would be to learn his views.

"Your statement that the proposal involves the purchase of half a million dollars' worth of land by the connected organizations further modifies my opinion. Moreover, I see in *Engineering News* of May 21st, just received, that a Joint Conference Committee of the Societies interested has passed certain resolutions recommending action by the several organizations, and that the plan involves a separate building for the Engineers' Club. I do not understand that it is proposed to merge all the different Societies into one, but that the proposal is that the National Societies shall occupy one common building, and the Engineers' Club another. It seems to me that acceptance depends upon the adequacy of the scheme to be devised for the ownership and management of the property to be acquired. The schemes hitherto suggested may be objectionable, but I think one can be devised.

"I believe therefore that an effort should be made in that direction. I am little in sympathy with the feeling that any one Society has a higher professional standing than another. Existing facts and conditions will, however, have to be recognized, and indeed, I believe that those enumerated by you would warrant the American Society of Civil Engineers in taking the lead, even if this involved some pecuniary sacrifices on its part. I am glad to note that the first step recommended is to obtain plans and estimates from Architects for the buildings.

"I believe that the land for the Engineering building should be owned by a separate corporation, whose stock should be taken in such ratios as may be agreed upon by the various societies in interest, in view of their probable use or financial ability. That each society should remain entirely independent in managing its own affairs. That each should occupy so much of the building as it actually needs, with proper regulations as to the alternate use of the larger auditoriums which would be but seldom occupied. That the libraries should be kept separate, but with provision to make the books accessible to members of the other Societies. That each should pay rent upon so much of the building as it uses. That other Engineering Societies should also be admitted by joint consent, and should also pay rent. That provision should be made for the future growth of each Society and consequent changes in the accommodation required. That inasmuch as not all the available space would be needed at first, and as the annual interest and taxes (for I do not believe that the latter could or should be avoided) might aggregate more than the present interest, taxes and rentals incumbent upon all the Societies put together, the

Discussion on Joint Engineering Building (continued).

surplus space should be rented to Engineering tenants acceptable to the Societies. That the profits should be kept small, and that, if any, they should be divided back among the stockholders (the Societies) of the new corporation, which might be managed either by directors elected in the usual way or by trustees appointed by the various societies upon some agreed basis.

"This is but a rough-cast scheme, made on the spur of the moment, and I hope that a better one will be produced."

Mr. Chanute's idea, as you see, involves a much more comprehensive scheme than the one now proposed. He suggests a huge building enterprise in which the American Society of Civil Engineers shall take the lead and enter into a speculation foreign to the purposes for which it is organized, and involving the expenditure of a much greater sum than is now proposed to be placed at its disposal.

Letter from Wm. Metcalf.

Mr. William Metcalf, another Past-President, wrote as follows:

"I am heartily in sympathy with your views as far as they deprecate any move that would jeopardize the independence and the high professional standing of the Am. Soc. Civ. Eng. Would it not be possible, however, to safeguard the standing of the Society and at the same time secure better located and better quarters in a great center of engineering activity?

"The most serious mistake in my mind is the including the Engineers' Club in any way. It seems to me that that feature is ridiculous. As to opposing any arrangement for a general engineering center, that would come with a bad grace from a Past-President of one of the other societies and a Past Vice-President of the third.

"I think you ought to publish your views in *Eng. News* and not let the argument go all one way."

The next of our Past-Presidents, in chronological order, is the distinguished ex-Chief-of-Engineers of the United States Army, Gen. William P. Craighill, whom the Society was glad to honor by admission to its roll of Honorary Members, seven years ago, after eleven years of active participation in the advantages of membership. I have seen a letter from Gen. Craighill opposing the present scheme, and supposed that it would be presented here. In response to my letter, he wrote:

"'I have been away from home and otherwise prevented from writing a suitable letter on the subject of accepting the Carnegie offer, but I am quite willing to be quoted as preferring a separate establishment for the Am. Soc. C. E., just as I think it best for my family to live in its own house and be independent, if possible.'"

Mr. Alphonse Fteley, another Past-President to whom I wrote, preferred to send his communication directly to the Board of Direction. You have heard it read by the Secretary.

Letter from Robert Moore.

Mr. Robert Moore, another and the latest of our Past-Presidents, wrote:

"When Mr. Carnegie's offer was first announced, I had the feeling that so generous and munificent a gift ought to be accepted if we could possibly do so.

"But as I have thought of it since then the probable or even possible gains to the Am. Soc. C. E. by the proposed union have become

more and more shadowy whilst the losses have grown in certainty and importance.

"Amongst the gains is a larger and more imposing meeting room and the ability to more readily meet the members of the other engineering societies. The larger meeting room, however, will hardly be needed by us except once a year at the annual meeting and this need can be more cheaply provided for by the use of Carnegie Hall or by an additional story on our present buildings. And to afford opportunity for meeting members of other societies is now the special function of the Engineers' Club and hardly anything else seems to be called for.

"On the other hand, by the plan proposed, the Am. Soc. C. E. will be obliged to give up its present home, over which its control is absolute, and take other quarters in which it will have only a one-fifth interest and in which its movements will always be subject to complication and control by others whose views and interests will not be the same as ours and may be adverse.

"The merger of the libraries of the different societies which has been suggested is, as I think, distinctly undesirable. On this point we in St. Louis have had a good deal of experience. The Engineers' Club which started out with its own library made, some years ago, an arrangement with the Public Library by which the latter, in consideration of the payment of a large part of the annual dues of the Engineers' Club, and the placing of its books in the Public Library, agreed to furnish to the Club a meeting room and buy such engineering books and periodicals as the Club might designate. After a number of years' trial the arrangement proved unsatisfactory and the Club withdrew from it, but without being able to withdraw its own library. A similar arrangement was then made with the Mercantile Library. But after a few years' experience this too proved a failure, and the Club withdrew to quarters of its own and began again the formation of its own library, which it is not likely ever again to give up. The Medical Society and the Academy of Science of St. Louis have had experiences which, though not identical with that of the Engineers' Club, teach the same lesson, viz.: that the small special library fills a place that can be filled by nothing else.

"In the same way I think that anything looking to a merger of the different engineering societies would be a serious if not fatal mistake. The fact that these younger societies have been organized indicates that there is a sufficient reason for their separate existence which any sort of organic union would defeat. But unless there can be an organic union the proposed union building will tend to promote dissension rather than harmony. It is a matter of universal experience that between different families harmonious relations are best promoted and maintained by not living under the same roof.

"From the standpoint of the Am. Soc. of Civil Engineers, therefore, I can see no advantages which will compensate for the loss of our own home and our complete autonomy."

Letter from Mr. Moore.

In a letter just received from Mr. Moore, which the President has handed to me for use in this connection, he says under date of June 7th:

"Though disposed to find reasons for accepting Mr. Carnegie's generous offer, I have been unable to do so.

"We are in such a good condition now that we have much to lose. If the several societies were united in one great organization I should

Discussion on Joint Engineering Building (continued).

say at once that the new building was just what we want. But such a Union of the societies is impossible and on the whole, I think, undesirable.

"But without an organic union the proposed housing in one building not owned by either will I think be an entanging alliance that will produce friction and discord and not harmony. It is the sort of experiment which with different families is almost sure to be disastrous."

I also wrote to Mr. John Bogart and Mr. Francis Collingwood, Past Secretaries. Mr. Bogart has replied by telegram to me here advising careful consideration of the questions by the Board of Direction and ts submission to a letter-ballot of the Society.

Letter from F. Collingwood.

Mr. Collingwood wrote:

"At first thought the prospect of a magnificent building devoted to the uses of the several Engineering Societies is very captivating.

"I can see, however, that in the case of our Society it *might* be obtained at too high a price, even though there is no actual outgo.

"There is much in the absolute quiet and restfulness of the present building which could hardly be maintained in the one proposed.

"The merging of the libraries, while enlarging the scope, might not prove an unmixed blessing.

"The several Societies being placed on a par, in so far as the ownership and occupation of the building are concerned, certainly would have a tendency to lower, in the eyes of the community, the standing of the Society as regards the professional qualifications required in members.

"The one thing that seems attractive in the scheme is the provision of a meeting room large enough for all occasions. Our own room is already too small at times of Annual Meetings. For everything else there is room enough where we are for some time to come.

"Large caravansaries are never favorable to study and useful thought; and I think we should know fully the complete details of the new scheme and be able to study it in all its bearings before coming to a conclusion."

I also wrote to the living Past Vice-Presidents of the Society who had not already publicly expressed their opinions, and received replies as follows:

Letter from Joseph P. Davis.

Mr. Joseph P. Davis, one of our most honored members, noted for the judicial quality of his mind, wrote thus:

"In my opinion it would be a fatal mistake for the Am. Soc. C. E. to enter into any partnership with other Societies for joint ownership of a building.

"I cannot imagine that the thought of doing so will be entertained by any large number of its members.

"We do not wish to be submerged. Your arguments against such action are sound."

Letter from Chas. Hermany.

Mr. Charles Hermany, an old and honored Past Vice-President, wrote thus:

"Your letter contains the first correct information I have received upon the subject. By this I do not imply that that which has been already printed is incorrect, but I must be permitted to consider that some of it has been premature, if not irrelevant; in fact, the

oracles seem in some cases to have left their temples, and upon the hustings and in the daily press have tendered their auguries with a freedom and profusion which fails of admiration. Someone should call these divinities back to their temples on Broadway and to those in other marts of our country.

"The commercialism which has in recent years dominated to some extent the engineering profession in its various activities has heretofore, and does now, threaten the survival of the professional engineer, pure and simple; and while this present movement, following closely upon the after-dinner speech of Mr. Scott, may not be a stroke of radical commercialism aimed at what to men of your and my experience is professional character, it is, nevertheless, for the time being, to be parried as such.

"My present inclination is to let the matter rest, with a grateful acknowledgment to Mr. Carnegie for his offer, which was undoubtedly prompted by the best of motives; at the same time, such a course would be a conservatism, the wisdom of which would be questioned by many, especially the younger members of our society. It behooves us, therefore, to consider the matter carefully, and I do not know but what it might be wise to have the question discussed at the Asheville convention. Moreover, we should always bear in mind the valuable contributions to practical engineering literature that have come out of almost pure commercialism in engineering.

"Inasmuch as we have had less than two weeks' time to consider this movement publicly, and because of my other engagements, I am not fully informed nor prepared to write more definitely upon the subject. In brief, I consider the movement in character similar to those made heretofore, but one of infinitely greater potentiality, and one that we cannot consider as a trivial event. It would take the prescience of a seer to perceive and express all that seems to me involved in this present movement."

That sums up this question of commercialism in professional engineering. The commercial element is very strong in some of the societies to which it is proposed to give a union building. They are technical societies, it is true, but there are many members who are inventors and manufacturers and dealers in commercial articles who do not take the professional view that the civil engineer does, and cannot take it. Now, at our conventions and at all of our meetings we have carefully excluded anything in the way of commercialism. We do not allow in the *Transactions* papers especially advocating personal interests. We do not allow, at our conventions or meetings, inventors or manufacturers to exploit their wares and solicit custom.

That is done at the American Water Works Association, which is very similar, in some respects, to the other societies, and I do not know why Mr. Carnegie did not include that in his gift, unless there were no members of the Engineers' Club present at that time who were members of the American Water Works Association; but we have always excluded that, and we do not want to have an intimate association with that class of society, nor do we want to have rooms provided in the building for the display of commercial products. We do not want to have the prevailing sentiment in that building such as exists in the Engineers' Club, and concerning which

Discussion on Joint Engineering Building (continued).

a prominent member of our Society, and a member of the Engineers' Club, and the Chief Engineer of a large enterprise, told me a few days ago that he had been a member of that club for some time, but he did not go there now because he wanted to get away from business when he went to a club; that he wanted to enjoy himself, and if he went into the Engineers' Club he had somebody running at him and trying to sell stop-cocks, or rails, or bolts, all the time, and that is the condition that it would get into, and you cannot get away from it.

Mr. Carnegie does not give this thing to one or two or three or four; he gives it to the five for a union building for them all, and they cannot divide that building under that deed. It is preposterous to suppose that under that deed the building can be kept entirely separate, when it is a Union building which is to be erected, so that the proposition made by Mr. Carnegie now is not one which the American Society of Civil Engineers can accept in any way; and that proposition is addressed to us personally and not collectively—by personally, I mean to the Society alone, to the American Society of Civil Engineers.

Now, this Society, it seems to me, must and ought to address to Mr. Carnegie a respectful letter stating that they acknowledge his gift with thanks for the kind feeling expressed, but that the whole sentiment and reason for being of the American Society of Civil Engineers forbids it to be associated on the same terms with a purely commercial and social organization. It would be up to Mr. Carnegie then to say what he wanted to do, and I have no doubt at all that Mr. Carnegie would see it, because he is a good business man himself, and he has associated a great deal with professional men, and he knows professional feeling; but he would see, if that was put before him, and brought before him in that way, that we were right and that he had been misled in this offer. The offer as it stands now, however, is not one which the American Society of Civil Engineers can possibly accept at all until the terms of the gift are changed.

Letter from Samuel Whinery.

Mr. Samuel Whinery, who was Vice-President in 1893, writes as follows:

"In the first place, the whole scheme is yet too vague to enable anyone to form an intelligent opinion upon the subject. We need to know in considerable detail the plan it is proposed to carry out. Particularly is it necessary to know what responsibilities the Society is expected to assume, and what liabilities it will incur by joining in the project. While we may indulge in some sentiment upon the subject, it must be considered primarily as a business transaction and upon its merits. The Am. Soc. C. E. has heretofore followed a wise and conservative policy which has resulted in a large degree of business prosperity. It cannot now afford to change that policy, in order to accept this magnificent offer of Mr. Carnegie. It must consider the matter deliberately and fully, and this will require no little time even after all the necessary data are in hand.

"The idea of the project is attractive and it seems reasonably cer-

tain that our Society would be benefited in a number of ways if it could be carried out satisfactorily. On the other hand, it is certain that the plan will be in many respects disadvantageous to the Am. Soc. C. E., however beneficial it may be to the other Societies. It is not possible for me, with my present information, to strike a balance or to determine on which side of the account it will be.

"As a general proposition I am inclined to favor the project. Furthermore, I think that our Society should be willing to make some sacrifice in the interest of her sister societies, provided the sacrifice be not too great.

"I should strongly oppose anything like an organic or even working union of the societies. I would make it a cardinal requirement that our Society must maintain its separate and independent existence just as it does now. The relation of the several societies would then be simply that of joint tenants of the proposed building. I do not see how such a relationship could seriously affect the character and standing of the Am. Soc. C. E. or lower its standards and dignity. We would continue to be the same society under the same management as now, but the location of our headquarters would be changed, and we would have in the new location certain increased facilities, such as a commodious hall for large meetings, and a good restaurant close at hand from which refreshments could be served, and where members could conveniently get good meals.

"With the stipulation named above—complete independence of organization and management—the question to be discussed is, as I said above, one simply of business and expediency.

"What will be the cost of interest and maintenance?

"What disposition can be made of our present house?

"If sold, how, and upon what terms can the proceeds be invested?

"To what extent will the Society incur actual and contingent liabilities?

"Will the new location be better or poorer than the present one?

"Will the advantage of a joint building and the facilities it will offer, overbalance the disadvantages of the change?

"These are to my mind the important questions to be considered; and they cannot be intelligently considered in the present embryotic state of the scheme. What we need now is a definite detailed project of the proposed enterprise, upon which to base opinions."

The writer of this letter is clearly not in haste to accept the gift and postpone scrutiny of its details.

I do not wish to tire you or detain you. There are not many other letters, except these. We have been told that the sentiment of the East was unanimously in favor of this proposition.

Letter from S. M. Gray.

Mr. Samuel M. Gray, of Providence, is a Past Vice-President of the Society, and he writes:

"I feel indebted to you for favoring me with so clear and impartial a view of the proposed 'merger' project.

"Certainly, all must appreciate and applaud the noble, disinterested, and philanthropic spirit which has prompted Mr. Carnegie to make his munificent offer; and it must assuredly give to the societies needing and meriting assistance, a newness of life; fresh encouragement in the fulfillment of the objects and purposes for which they were organized, and that they have been able but partially, perhaps feebly, hitherto, to attain.

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"But while this may be true, and doubtless is, regarding one or more, perhaps all, of the other organizations you mention as beneficiaries in the scheme proposed, it cannot be said to be so of the American Society of Civil Engineers, and I desire to say that I believe the American Society has but little, if anything, to gain and much to lose by favoring the 'merger' proposition."

Letter from Chas. Macdonald.

Mr. Charles Macdonald, a Past Vice-President, says:

"I have read your letter with a great deal of interest and have given it the most careful consideration.

"Let me say, in the first place, that I consider you have not only presented a 'fair statement of the case,' but an admirably clear and logical description of the relations which exist, at the present time, between the organizations referred to. Nevertheless, I am compelled to urge upon you the importance of wisely and patiently investigating the possibilities of the future development of the profession, before committing yourself to the belief that the American Society of Civil Engineers will always hold first place. For my own part, I have never held to the belief that the Engineer required any qualifying adjective to designate his rank. In the earlier stages of development, it is true that the necessity seemed to exist for a proper distinction between the designer and constructor of Engineering work and the skilled mechanic who could operate it, and as such Engineering work was in general carried out on commercial lines, it was natural that the constructor should be called a Civil Engineer, as distinguished from a Military Engineer, or from the mere mechanic, who operated the work, after construction; but in the process of time, it has become evident that the differentiation of activities grouping themselves under the general head of Engineering, cannot be for long restrained, under any designation which does not permit of the most comprehensive title, for the man who utilizes the forces of Nature for the benefit of his fellow men. Up to within a century, we have been utilizing forces of Nature, which were of comparatively simple application, but with the invention of the steam-engine a new line of activity presented itself and now the Mechanical Engineer has acquired a right to the use of a qualifying adjective, so long as such distinction is considered necessary. Later came the utilization of electric energy, of which we are as yet but upon the threshold. Judging, however, by the tremendous strides made of late, who shall say what the future of that branch of the profession shall be and whether the infant society of to-day shall not over-shadow all the other societies, in the near future?

"I, for one, do not feel like taking the risk of waking up some day and finding the dear old A. S. of C. E., which you and I have helped to build up, forced into the background of Engineering progress, by a child of to-day, but a child endowed with all the power and potency of illimitable growth, and the sooner we recognize it the better. Now, you will naturally say, what scheme have you to suggest, whereby this offer of Mr. Carnegie can be turned to the best account. This is not an easy question to answer and I have not had time yet to consider all the reasons *pro* and *con* involved, but I can see in my mind's eye, deeply engraven in stone, over the capacious entrance to the building which is to be, the superscription,

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and I am firmly convinced that the leading men of our several organizations will be able to work out a plan under which each may maintain

its individuality in this temple of applied science, and yet all will work together, for the general good of the profession, which we love so well."

Now, the difficulty about Mr. Macdonald is that he does not understand, or he has not got the meaning of civil engineering. It is not engineering with an adjective. It is as the Germans write it; it is "Civil-engineering," all one word, and "Civilengineering" is what Thomas Tredgold said, in his well-known definition, is the art of directing the great sources of power in Nature for the use and convenience of man. Now, that includes all the branches of engineering, and the term "Civil Engineering" is not, and is not generally understood to be, applicable to any one branch of the profession of civil engineering. The tendency is, I know, among certain classes, among men who are not members of this Society, to say that the civil engineer is simply a man who does not belong to one of the other special societies; that is, he is not a mechanical engineer, or an electrical engineer, or a mining engineer, when he is a civil engineer. That is entirely incorrect, and the general impression, the general sentiment of the profession is not as thus expressed. I don't know what would happen after the development of the electrical engineers, but I think Mr. Macdonald looks forward to the day when the American Society of Civil Engineers will be "dissolved into a multitude of revolving electrodes," which Sir William Crookes thinks will be the fate of all matter.

To show you that the sentiment of the Society is not so universally in favor of this movement, I will read a letter from a Past Vice-President of the Society, in the State of New York, Mr. Robert Cartwright, of Rochester. He writes:

Letter from R. Cartwright.

"I am heartily in accord with your views in the matter. As a Society in this country, we are the only one that I have any knowledge of, that insists on maintaining a standard by which to regulate the acceptance of its members as being qualified for such position. To preserve that standard intact has always been my aim in my official connection, so that its status should be maintained among the best organizations in Europe or elsewhere. To be affiliated with the A. S. C. E., it is not enough that a man should be a good fellow, as is the case in some societies, but that by his professional experience and his integrity, he should be found worthy by his professional brethren and be honored by being elected to membership in the Society, based upon a standard or rating as required by the A. S. C. E.

"I honor Mr. Carnegie for his disinterested generosity in his efforts to benefit his fellow men, and can see how self-appointed, interested parties might make an appeal to his better nature that would impress him favorably, but I cannot endorse a project that embraces all kinds and conditions of societies, whose only claim to recognition is a body organized under some scientific appellation, and whose members are absorbed without any regard to a standard of merit. As you justly say there are many men in such societies who are the peers of any in the A. S. C. E., in capacity, in integrity, or in financial standing, but so long as they are not selected on a basis as high as that required by us, it certainly would not be equitable that we should go into partnership

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with them. The Engineers' Club is purely a Social Club and I can't see that they should become participants in Mr. Carnegie's generous plan. Our A. S. C. E. is an organization that is recognized by the whole civilized world as a power. We have our library and our property and are self-supporting, and it does not strike me favorably that we should lower our standard of qualifications and throw all this into a common fund to be participated in by all societies, however ephemeral or social or scientific, that may from time to time come into existence. Our Society is made up of material from all branches of the engineering profession as evidenced by our Constitution in Article II, Section 2, and is certainly broad enough to take in any person possessing the necessary qualifications. We are either something or nothing, and I should emphatically oppose our being merged into a conglomerate mass that is made up of any and everything, named by the promoters for the purpose of being fostered and supported by the large-minded, generous Andrew Carnegie. I honor him intensely and I believe were the thing properly presented to him, he would so perfect the scope of his donation that its future would be a great one, calculated to improve the profession and still retain the exclusiveness pertaining to ability and integrity. When his beneficence absorbs social clubs, *et al.*, it certainly would not confer any honor to become a participant.

"I regret my inability to attend the Asheville meeting in order to participate in a discussion of this subject, but I think that the sober common sense of the A. S. C. E. will result in a just solution of the question."

After writing that letter, Mr. Cartwright thought it would be a good thing to see what the Rochester contingent of the American Society of Civil Engineers thought of it, and they all signed it.

"We heartily concur in the foregoing."

"Justus Herbert Grant, M. Am. Soc. C. E.
"William E. Hoyt, " " " " "
"J. Nelson Tubbs, " " " " "
"John F. Alden, " " " " "
"W. N. Radenhurst, " " " " "
"Geo. W. Rafter, " " " " "
"Le Grand Brown, " " " " "
"J. Y. McClintock, " " " " "
"E. A. Fisher, " " " " "

Letter from P. A. Peterson.

Mr. P. A. Peterson, of Montreal, another Past Vice-President, writes:

"In regard to the amalgamation of the various bodies of Engineers and others of the City of New York, consequent upon the offer by Mr. Carnegie of a million dollars to put up a Union building, I am very much opposed to such an amalgamation as I can not see what the Am. Soc. C. E. is to gain by it, and I can see very much what we shall lose—viz., the management of our affairs, and the prestige which we have gained which should be enough to keep us out of any scheme of Union unless the terms are very different from what I suppose them to be."

Letter from G. H. Benzenberg.

Mr. George H. Benzenberg, Past Vice-President, writes thus:

"I do not yet fully understand to what degree these Societies are to unite to carry out the proposed merging of their property interests,

and whether the affiliation is to be of such a nature as to partially obliterate their characteristic individuality.

"Should the scheme contemplate this latter proposition, in other words, remove the restrictive requirements of this Society, I should think that not any of its members would consider such a scheme seriously. If it is proposed that each of the five associations shall contribute one-fifth towards the purchase of the real estate necessary for the building, it seems to me the burden might become too great for some of them to assume, while, if the property is to be paid for upon any other basis, the tax might become too great for the others, besides which the unequal interests thus created may in time, with the more rapid growth of one or the other, become unsatisfactory. These matters must all be considered so as to guarantee such an alliance to be as satisfactory to all parties concerned in the future as well as at the present time, as the partnership cannot hereafter be dissolved without sacrifice to one or the other party.

"No definite action towards entering this combination should therefore be taken by this Society until it is definitely established upon what basis it is to unite with the other Societies, what obligations it is to assume and how its interests, if acquired, are to be protected and administered. Every member has a personal interest in this question and should be permitted to voice his conclusions after having been fully advised as to the proposition and the obligations assumed.

"It is quite natural that a difference of opinion should arise among the different societies regarding this matter as well as among the members of our own Society, notwithstanding each has the best interests of the Society in mind and is entirely sincere and unselfish while formulating such opinion.

"The whole subject at present is undoubtedly surrounded by a great deal of pardonable sentiment, but before long it must naturally resolve itself into a simple business proposition, and in order that the alliance, if contracted, may always, individually or mutually, be fair, comprehensive, agreeable and beneficial as well as permanent, it is necessary that it be given unprejudiced and deliberate consideration before any entangling obligations are assumed by any of the parties.

"The question cannot justly be disposed of as if there were nothing at stake aside from participating in a most generous contribution. Joint financial interests are not always conducive to maintaining the most pleasant or friendly relations, unless they are previously well defined and determined.

"It seems to me the most vital question is not as to what convenience may be secured to the Societies and their members through the munificence of a generous admirer of the engineering profession, but what can be done to permanently advance the interests, standing and recognition which is due to it.

"Careful, deliberate and exhaustive investigation previous to arriving at conclusions is the safeguard of successful Engineering. I would suggest that this principle be applied here as well, as there is certainly no haste required in this matter. If it is a good thing it will keep."

Letter from Rudolph Hering.

The last letter to which I will ask your attention is from Mr. Rudolph Hering, a Past Vice-President. He writes:

"The acceptance of the generous gift of Mr. Carnegie, as I stated, is no more degrading to our Society than a similar gift to Universities

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and other institutions of learning. I think it is hardly fair to say that our 'Society is not an educational institution, but an association of men who have acquired such an education.' What is the purpose of a library except for spreading knowledge and learning, and why do we read papers at our meetings and publish them, except to instruct our fellow members regarding our own research or experiences? I confess that I have never attended a meeting without learning concerning some engineering work, and whenever this education among our members should cease, our Society, it seems to me, would become a mere social club. Although such a club is excellent in itself and for its special purpose, I trust that to adopt its functional character will never become the policy of our professional Society, which has for its main object 'the advancement of engineering knowledge.'

"The second point of your letter is the statement that it is inconsistent for our Society to be associated in the same building with other organizations having a lower standard of membership. I fail to see that it is in any way harmful to a member of any branch of the profession to associate with others who are either younger, less experienced or less well informed in our own special line of work than we are ourselves. He whose mind is open to advancement will find instruction from every progressive and freely developing mind, even though younger and less experienced. You write that the general public will assume that persons so associated in the same building must necessarily all stand on the same professional plane. I think this will be no more the case than the assumption that the members of any single one of our societies all stand on the same plane, although enrolled in different classes of membership.

"Very few engineers who do not wish and expect to be improved in some ways by their new associations ever join a professional society; all but very few will advance by the new intercourse. If the American Society of Civil Engineers maintains the highest grade of membership, I think a closer association with other societies would have the effect rather of gradually drawing the grades of others upwards than ours downwards. Since the birth of our own, the oldest of the societies, this gradual upward tendency has been quite apparent in its successive constitutions, and the highest limit I hope has not yet been reached. The other societies will no doubt develop the same tendency and, consistent with the more rapid recent progress in engineering, they may develop even more rapidly than we did when younger.

"The proposed union is limited practically to the housing and to the material and social interests. It is not to be extended to the professional interests and professional work. Therefore, I do not see any fundamental difficulty in gathering the several branches of engineering under one roof and yet preserve the fundamental characters of the respective constitutions.

"The only difficulty, I believe, lies in the business aspects of equitably dividing and arranging the respective properties and of their management. Mr. Carnegie proposes to divide his donation equally among the societies, which would have the effect of increasing the present property of each one by a definite sum. The American Society of Civil Engineers being at present the largest and wealthiest of the several societies, could by adding from its own funds have the largest quarters and any special conveniences which it desires and for which it can pay. It would own for itself just what it puts into the new and common property. The libraries and much of the other present properties could remain as now with each society. The auditorium common

to all the societies could be made larger, handsomer and more suitable than is possible if each society had a separate house. It would be used more frequently, be the gathering place of all visiting engineers and become a temple of American engineering.

"So far, I see no reason why suitable committees could not arrange the business end of such a joint occupation, in order to secure a fair, just and satisfactory system of housing the societies under a single roof, preserving to each one their present full independence wherever this is necessary and proper. Nor do I see any reason why a governing body, elected in proportion to the membership, would not properly represent the societies separately and as a whole, and properly manage those interests which are common.

"I do see a good reason, however, for drawing a distinct line between the professional societies and the social club. I understand it is the intention of having for the latter an entirely separate building, although adjoining, and this arrangement should obviate the criticism of a close union with, as you say, 'an unprofessional, social and commercial organization.'

"For one, I would be willing to trust representative committees of each society to make a careful investigation of the subject in all its bearings, and after a full discussion between such committees, and after all aspects are presented to the members of all the societies, I should also trust a ballot to decide the proper policy."

It is to be regretted that in commenting on the propositions submitted, Mr. Hering should have based his remarks largely upon sentences which he has quoted only in part, and which, therefore, convey a very different meaning from the complete sentence.

As regards education, we all agree that, in a certain sense, all conversation and intercourse between men is educational, but a society like ours cannot, in my opinion, be properly termed an "Educational Institution." That term I understand to be applied to an institution in which regular courses of study are pursued under the direction of persons skilled in particular branches of learning and possessing the faculty of imparting information to students, and examining them to find out how much they have absorbed. I do not consider the term applicable to an association of experts in co-ordinate branches of science for the purpose of exchanging their ideas and experiences. The members of such an association do not "sit at the feet of Gamaliel" and accept the law as he lays it down, but they have Gamaliel down on the floor with them and question and criticise his dicta, and probably teach him as much as he teaches them.

As for elevating the tone of other societies by simply having them under the same roof, I fail to see how this can be accomplished.

As to the proposition that the technical societies should be kept entirely separate and apart from the social and commercial element, the only reply is that the gift is for a union building, and the promoters of the scheme, in speaking of the advantages of the location, speak of its fronting on Fortieth Street and Bryant Park. That is the front door of the Engineers' Club. To get to the Engi-

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neers' building you have got to go through the back door of the Engineers' Club, as proposed.

I do not know that I have any definite proposition to make on the subject, but I do think that the proper method would be, as I have indicated, for the Society to write a respectful letter to Mr. Carnegie stating that we appreciate his gift, but that the conditions attached to the gift are such that the Society cannot consistently with its professional standing accept it. (Applause.)

OBERLIN SMITH, M. Am. Soc. C. E.—Mr. President, Ladies and Gentlemen: We have heard some strong testimony from Mr. Croes and the people he did write to. I want to ask him if he can give us the opinions of a lot of the fellows he did not write to?

As I happen to be a member of all five of these organizations, I feel as if I might be able to look at the matter impartially, and as though I could see the difficulties that surround this question from various standpoints.

I do not pretend to say that we want to jump right into the arms of the present committee and Mr. Carnegie, and swallow the whole thing just as it is. It is a subject that requires consideration, but I want to answer, as briefly as I can, three or four things that have been said to-day. I think there is too much tendency in this Society—I have heard it as a rumor, and I begin to feel this afternoon as if there might be some truth in it—to think we are "It"—to use a slang expression—and that if all the members of the other societies who are engineers practicing their various vocations would only disorganize and become members of this Society, this would be the great Society, and all would be right. If that could be done I would gladly help. I do not know what the proper name would be. The name suggested by Mr. Macdonald, "The Institute of Engineers," would be in good taste, but I do not hope to live long enough to see it. I hope somebody in another generation will see one organized in that way, with all the smaller societies forming chapters of a greater body, but we can hardly hope for that now.

The great pity is that this plan proposes to face the building on two streets and not on Fifth Avenue. We ought to have a large building, of beautiful architecture, bounded by streets on two or three sides of it at least, but we cannot get that now. The only question is the practical one, shall we take this magnificent gift for our Society, or will we consider that the entire independence which the Society now has may counterbalance that two hundred thousand or a quarter of a million which would be our share. If so, well and good; but there are other reasons why we cannot afford to let this gift go, and give it up to the other societies.

I think there is a mistaken opinion among a good many of the members of this Society who do not happen to belong to the other

societies and do not go to their meetings, about the character of the other societies. It is not true that they are places where goods are bought and sold, like some of the Railroad Associations. At the Mechanical Engineers', the Electrical Engineers' or the Mining Engineers' Societies there is nothing of that kind. I know the character of the papers which are presented and the discussions thereon, as well as the character of the members in the Mechanical Engineers, and it is as high as in the Civil Engineers. There is as much science and as much intellect as there is here. They are men of the world and they stand as high socially. In the Electrical Engineers they are men who carry on special work requiring much learning. The Mining Engineers, unfortunately, have some members who are not scientific men, but those who are do not go there for commercial purposes, and they are men of high grade, good training and high talent for engineering.

I want it thoroughly understood that if we are all going in together it is not a case of one society taking in all the little beggars to nurse them and care for them; it is not a question of "leavening the lump" as has been said. We do not want the feeling to grow that they are affiliating with this great and grand old Society. It is nothing of the kind. It is the feeling that has been with many of us for many years throughout the engineering profession in this country, and not only in the profession itself but in the eyes of the whole engineering world. We should overlook our petty jealousies and work together more, and get that harmony of action and more intimate acquaintance with each other which we need to come nearer together,—and, after all, I regard this whole matter as simply geographical. It is bad for people in a similar business to be too much separated. You cannot do the stock business of New York City in four or five stock exchanges miles apart, and so it is in all trades and businesses. Concentration is the modern thing. Bring people together where they will see each other and where they may work with each other and work together. Therefore we want the societies near together. If they were in four separate buildings connected with tunnels under the street, that might be an ideal thing. If not, then have one building and have it situated and arranged in such a way that we are not treading on each other's toes, having our own privacy, but yet being near together. It is not a merging of societies. It is merely a question of policy and expediency, and a matter of bringing us together where we may get and do more good to each other.

A man may now bring a friend from the West to New York, and he may have but a little time at his disposal. Perhaps he goes into the Engineers' Club—and by the way, I have a great respect for this Club, notwithstanding the statement that the high-balls which they have there are driving all the juniors to an early grave—but he should be able to call in at the Society Houses also, without traveling all over

Discussion on Joint Engineering Building (continued).

town. I must say that I am sorry the thing has taken the shape that it has here. I know most of the men who have gotten the thing started—Mr. Scott and the others—and I think that they deserve a great deal of credit for doing what they have done. There is no secret conclave; there is to be a big committee appointed for all the societies, and all interests will be watched carefully. That Committee must be trusted to do what is right.

Mr. Carnegie knows that the club is not a technical society, but a purely social club, though containing many engineers. If he chooses to give it a present, let its building be owned by itself. The other building, anyhow, merely abuts on the Engineers' Club. Let the four societies come together as has been so often proposed, and the fact that the Engineers' Club is close to them will be a great advantage.

A man comes to New York, a stranger, and goes to a hotel; he is in a hurry, and he wants to meet engineers, and he inquires where the engineering people can be found. He is told that the Electrical Engineers are down town, the Civil Engineers are a mile up the street, and he says, "57th Street; that is too far; I haven't time to go there. Where can I meet so and so?"

It has been said that this Society will get only one-quarter or one-fifth of the property. That is not so, because we will get a share of an enormous hall, perhaps more than our exact proportion (laughter). The reason the Mechanical Engineers have to go out and hire hotels is because they cannot use their own rooms. Their hall is not big enough. Let us have a hall that is big enough for anybody and for any kind of an engineering meeting. It can be let out to the Association for the Advancement of Science and other big societies here and from abroad. It will be a place where all Science can have its headquarters. Let us have it big enough. There may not be another chance.

This Society should not take too much credit because it happened to be born first, but it had better look out not to get in the back seats by too much delay.

Now, about other societies coming in and backing out afterward, not paying the interest on their share of the loaned money, there could be arrangements made, I think, to force them to give up their holding. If they are bankrupts they cannot stay there, and we do not want them. Why can't they go out and leave the property to the rest of us?

I think that we ought to look at this whole thing from a larger standpoint than any of us have done yet. What would be the effect on the engineers of this country, and upon engineers in Europe and all over the world, if this Society holds itself so close that it cannot come in with the other societies? Those societies are great, growing

and enterprising, and so recognized all over the world. They come together and accept this magnificent gift and run the thing, and it increases and becomes famous, as it will, and this American Society of Civil Engineers cannot afford to be left out.

I therefore am in favor of this resolution except that I wish to offer an amendment to it. I do not remember the exact wording. Mr. Hunt will doubtless supply me with the clause, the portion where it says that the Board of Direction shall be instructed to examine into the feasibility, etc., and then issue a letter-ballot. What is the exact wording?

THE SECRETARY.—Perhaps I had better read it over.

(Resolutions read. See p. 226.)

MR. SMITH.—To that last resolution but one, where it says "Resolved, that they send a letter-ballot," I offer, in amendment, to insert the words "within sixty days." If that is not proper we can make it more, but what we have to fear in this matter is that the thing will be delayed—hung up, so to speak—and go on for months and months. The other societies have acted promptly, in good spirit. Mr. Carnegie is a man of business, and wants to do business, and do it quickly. We don't want to linger. We should send out this letter-ballot and find out what the Society wants. The members of this Society must rule, and we can thus find out, and soon.

THE SECRETARY.—The Board offers the resolution to the Society for adoption.

MR. SMITH.—I offer that amendment.

THE PRESIDENT.—The question before the house is on the adoption of the resolution reported by the Board.

H. S. HAINES, M. Am. Soc. C. E.—If I may be pardoned for inserting one word to facilitate this thing, I suggest that this gentleman's amendment be received and laid upon the table and taken up at an advanced stage of this discussion. We have gotten along in the afternoon and we have endeavored to concentrate our attention on the remarks of the gentlemen who have prepared themselves fully to give us information *pro* and *con*, and I, for my part, do not feel that I am physically able to act intelligently if this thing is brought to a vote now, and if we begin to take up one amendment after another and discuss it for what it may be worth, good or bad, it will be a long time before we get to the subject which is germane to the whole discussion, and that is the resolution which the Board of Direction has offered to us for our action. At last, that is the thing we are going to get to, and that is the thing we are going to discuss. When that time comes I hope to have the opportunity to express some views on the subject myself, and when I do, I want to ask that they may have as careful consideration as you have given to the remarks of the gentlemen you have already heard; therefore, I hope that the gentleman will

Discussion on Joint Engineering Building (continued).

not understand that I am endeavoring to prejudice his argument, but I ask that it be received and laid on the table to be brought up at a later part of the discussion.

MR. SMITH.—If this discussion is to go on through the Convention I should gladly have it delayed, but I don't want to have it laid over until some other convention. If we may continue the discussion to-morrow or at some other time, that will be satisfactory.

MR. HAINES.—I hope the gentleman does not think that I want to interrupt him, but if that amendment can be laid on the table to be brought up at a later stage of the discussion, he can go on to the other branches of the argument without prejudice to it.

THE PRESIDENT.—Mr. Smith has the floor. Does Mr. Smith yield to a motion to lay the subject on the table?

MR. SMITH.—The whole subject?

MR. CROES.—The motion is, I believe, that it be laid on the table. I don't think that is at all necessary. I think this is the most important subject that will come before us, and we had better simply adjourn this meeting until, say, half-past nine or ten o'clock to-morrow morning.

MR. HAINES.—I do not propose to lay the resolution of the Board on the table. I propose that the gentleman's amendment to those resolutions should just be laid on the table temporarily, to be brought up at an advanced stage of the discussion, that is all.

MR. CROES.—That will be better accomplished—a motion to adjourn is always in order—and it will be most effectually accomplished by adjourning now to some named hour to-morrow.

THE PRESIDENT.—The Chair is under the impression that the amendment of Mr. Smith is not seconded, and the question is upon the resolutions offered by the Board.

MR. SEAMAN.—I would move, Mr. Chairman, that we adjourn until to-morrow morning at 10 o'clock.

MR. SMITH.—I second the motion.

THE SECRETARY.—Will you allow the Secretary to say one word? It will be a physical impossibility to hold two meetings at the same time, I think; and the programme, which has been very carefully laid out by the Committee in charge of this Convention, provides very fully for all of the time during the Convention, except the meeting for Friday morning which is the last day of the Convention.

MR. SMITH.—I believe the question is on the motion to adjourn.

MR. CATT.—May I say just one word? I move to amend the motion to adjourn to to-morrow at nine o'clock, at which time this question may be taken up and discussed for one hour. The motion to adjourn to a fixed time is capable of amendment.

The motion was seconded.

MR. SEAMAN.—I do not think any business that will come before this Convention compares with this in importance, and I think that if

to-morrow morning's business is postponed until Friday morning, it will be just as well as to have it to-morrow morning, and if to-morrow we do not have time to discuss it fully, eliminate it altogether, and we should adjourn until ten o'clock to-morrow, and then, if necessary, continue it. I would move that we adjourn until ten o'clock to-morrow morning.

THE PRESIDENT.—The Chair will entertain a motion to adjourn; the motion is not debatable or amendable.

MR. SEAMAN.—I don't know who made the original motion to adjourn.

MR. CATT.—I simply want to call your attention to the fact that a motion to adjourn to a fixed time is a debatable motion.

THE PRESIDENT.—The motion before the meeting, the Chair believes, is a motion to adjourn without fixed time, and it was seconded. Such a motion has to be put to vote without debate. The Chair will put the motion.

MR. SEAMAN.—I do not see why we should restrict ourselves. The only objection to this whole procedure is trying to limit the discussion on this subject. There is nothing that can come before this Society at this time that compares in importance with a full and free discussion of this subject. If we adjourn until to-morrow at 10 o'clock, we can then adjourn at 11 o'clock if we are through with the work.

THE PRESIDENT.—It is quite within the power of the meeting to vote down the motion to adjourn.

MR. CATT.—I would like to change my motion to amend, if Mr. Seaman will permit, to call the meeting earlier to-morrow morning and leave open the question of how long we will discuss this question. Make it 9 o'clock instead of 10. I would like to see him do that.

THE PRESIDENT.—Does Mr. Seaman accept the motion to adjourn until to-morrow at 9 o'clock?

MR. SEAMAN.—Yes.

THE PRESIDENT.—Those in favor of adjourning until 9 o'clock to-morrow for the resumption of the discussion of the matter will please say aye.

The motion was carried.

(At 5.50 P. M., adjourned to Wednesday, June 10th, 1903, at 9 A. M.)

BUSINESS MEETING—(Continued).

Wednesday, June 10th, 1903.

The meeting was called to order at 9.45 A. M., President Alfred Noble in the chair; Chas. Warren Hunt, Secretary. Meeting called to order.

THE PRESIDENT.—This meeting is held pursuant to adjournment yesterday to continue the discussion of the proposition for a union

Discussion on Joint Engineering Building (continued).

engineering building. Mr. Oberlin Smith had the floor when the meeting adjourned.

MR. SMITH.—Mr. President, I will withdraw the amendment that I offered to the Board's resolutions in regard to a time limit. On further thought, there is little question but what, if the Board has the matter in charge, they will do right. I believe they appreciate the importance of the matter. Whatever may be the opinions *pro* and *con*, there are arguments on both sides about this Society affiliating with the others that can be decided only by the membership at large. It cannot be decided by this small Convention in any fair way, and those resolutions that we are voting on are simply to put it before the Society so they can vote on it. It does not commit us as a Convention or any of us as individuals to voting for either policy. It simply looks at the great scheme, which has come up, with impartiality, and arranges to put it before the membership at large, where it ought to go. I do think, and would urge on everybody concerned, that we ought to make haste. The thing has gone some time now since Mr. Carnegie made his offer, and due diligence should be exercised by all the societies in coming to some harmonious action on the subject.

I believe the Committee of Fifteen, as far as the Club and the other three societies go, has members appointed by authority of the Boards of those societies, but the three members who acted from this Society, as I understand it, were doing so only informally. I suppose our Board will attend to that matter, and when they do take it up, will appoint a committee, perhaps of three, which will confer with the other societies. I, for one, sincerely hope that, although the Engineers' Club is a good thing to affiliate with, socially, professionally and geographically, yet we should not be five partners in the legal sense of ownership of the property. The four societies can work together, and although one is older and a little bigger than the others, yet the young ones are growing, and I want to insist again on the professional status of those other societies as being remarkably respectable. (Applause.)

MR. HAINES.—Mr. President and Gentlemen: I listened with a good deal of attention to the remarks that were made here yesterday, and in order to keep my own remarks from being too diffuse, I have taken the liberty to reduce them to writing. I do not wish you to suppose it is a speech.

I came here with no more information on this subject than could be gained from the daily papers. I have listened attentively to all that has been said, and in my remarks I shall speak from a standpoint which I hope and believe is occupied by most of the members here present—that is, the attitude of an inquiring mind.

At first sight, one is attracted by the proposition made by Mr. Car-

negie, so unexpectedly, with such munificence that the judgment becomes confused and dazzled with the view of apparently unexampled possibilities in the way of co-operation for the advancement of the engineering profession. It is well, therefore, that we should have heard the views of those who have carefully prepared themselves to present this proposition to us, stripped of what has been termed its glamour. After hearing these arguments, we must wonder what is left to be said in its favor.

About one thing I feel greatly relieved. I was glad to hear that the other societies to whom this proposition has been made have already determined to accept Mr. Carnegie's offer, regardless of what action this Society may take. I say that I am glad of this, for we now feel that we are free from any responsibility to them, and that we may consider the proposition solely as affecting the welfare of this Society, without any scruples of conscience as to how our actions may affect their welfare.

Before I make any suggestions in this line, however, there is a word that I would like to say with reference to the sarcastic remarks made at the expense of the Engineer's Club, which added so much to the gaiety of yesterday's session. I listened to these remarks with pain, for I have been a member of the Engineers' Club for nearly twenty years. I see in this assemblage faces which are familiar to me as its members, and the faces of others whom I have seen there enjoying its hospitality. The Engineers' Club has a membership of a thousand members and a large waiting list. It is a prosperous club. I have never heard of its asking alms. Some of its members formed a real estate corporation, and with their own money purchased the building site on Fortieth Street that has been facetiously mentioned here as the back door of the future building of the Engineering Society. I have been on its Board of Governors for five years. I am therefore familiar with the scrutiny to which all applications for membership are subjected. I have had a somewhat similiar experience in the management of this Society, and I am therefore prepared to say that the social standard of membership in the Engineers' Club is fully as high as in this Society. I do not understand that the Engineers' Club sought Mr. Carnegie's money, and I imagine that the majority of its members know little about the merits of the proposed affiliation of the engineering societies, and care less.

It seems, however, that certain gentlemen officially connected with that club, in the ardor of their zeal for its welfare, were imprudently led to associate themselves with this objectionable proposition. Their names have been mentioned in this meeting by those who know nothing more of them than that one of them has occupied an official position in this Society. I may say that I have known them long and well, that I am proud of possessing their friendship, and I feel sure that

Discussion on Joint Engineering Building (continued).

there will be no lack in this meeting of a confirmation of what I have stated.

If I have been led to speak at some length in the defense of the Engineers' Club it is because of the remarks concerning it which I think have been unnecessarily interjected into the discussion, and if what has been said to its disadvantage is to go on record in this meeting, I shall expect that what I have said in its defense shall likewise go there.

Now, I shall confine my remarks to what I consider to be specifically the matter before us, and that is the consideration of the resolutions that the Board of Direction has prepared for discussion at this meeting.

Gentlemen, I ask you to think for a moment as to the origin of these resolutions. They have been prepared by your Board, which is composed of members elected—and elected by a Society vote—from every district represented in this body; men who have the welfare of this Society at heart, and who have carefully weighed the effect of the action which they have recommended you to take. Therefore, these resolutions are entitled to your respectful consideration, and, to my mind, the burden of proof is not so much upon those who speak in their defense as upon those who speak against them. The action suggested by the Board is the result of their investigations made with ample opportunity for arriving at a just conception of the nature of Mr. Carnegie's proposition. Have they flouted at it? Have they indulged in jibes and jokes at the expense of the other societies whose names have been associated with the American Society of Civil Engineers? Far from it. They have approached the subject with a seriousness worthy of its importance. And what have they recommended? Why, that you should properly authorize the Board to make such investigation as will enable the proposition to be submitted to the members for a letter-ballot, intelligently.

What more is proposed? What else can this Society do without exposing itself to the charge of a lack of decency. Who is there that is authorized to reject such a proposition on behalf of this Society except its members, and who is there that will assume to take such a responsibility to himself?

In all that I have said I have not said one word in favor of accepting this proposition. Indeed, I appreciate the force of the argument so carefully prepared, so conclusively presented by our honored Past-President, to whom this Society has been greatly indebted throughout its existence—an argument powerfully reinforced by the opinions of those other eight of our honored members, his peers in the past history of the Society.

I recognize the proud position which our Society has attained. I love the comfort and quiet of our beautiful Society House, our own

property, paid for by the contributions of our own members. Not the one-fifth of Mr. Carnegie's gift, not the whole million dollars, if presented entirely to our Society, could add one iota to my enjoyment of the privileges which I so highly value as a member of this Society.

No, Mr. President, it is not for such gentlemen as have been named in support of Mr. Croes' argument; it is not for those who, like myself, have benefited by our past association with the Society, that this proposition offers any advantages. For me, I should far prefer to enjoy what we have in dignified independence.

I listened with interest to the remarks made at the opening of yesterday's session by our Past-President, Mr. Wallace, and to his words of wisdom, after presenting the germs of all that bears on this discussion. My sympathies were entirely in accord with the sentiments which he so forcibly expressed, but he said one thing which has stuck in my mind and which has made a different impression from what he intended. He said that if we should take the step of affiliation with the other Societies, that instead of our Society holding its present proud pre-eminence as the representative of every branch of engineering, we should be placed in the position of representing only a remnant. That is a serious thought—that the American Society of Civil Engineers should ever be put in the position of a remnant. Why, if this is to be the logical conclusion to be drawn from the proposition submitted to us, there can be but one answer to it. Better go back to our former humble abode on Twenty-third Street than to occupy a gilded palace with such a lamentable result. But is there another application of Mr. Wallace's thought? Is it possible that by a process of exclusion we may drive from our membership the mechanical, electrical and mining engineers, and by a further process be deprived of the sanitary engineers, for instance, and the engineers who are contracting for all the municipal and structural works, commercial engineers, if you please? What sort of a residuum would be left to us then? Is the tendency of modern engineering activity to strip our noble tree of one branch after another until nothing is left it but a lifeless trunk?

It is not for the older members of the Society to decide this question; they have no interest in it. This Society will last their time in all its strength and prosperity. It is for the younger members to ponder over. It is a problem which affects their future. I hope that they may solve it as wisely as their predecessors have solved those which have come before them.

At all events, I appeal to every member present to vote for the resolutions presented by the Board. I had proposed to say, without amendment; but it has occurred to me that perhaps their resolution is open to this objection, that the vote upon them by the letter-ballot is intended to be called for—when?

Discussion on Joint Engineering Building (continued).

THE SECRETARY.—Within a reasonable time.

MR. HAINES.—It seems to me that it would be better to provide that this very important matter should take the same course that all other matters of importance have taken in this Society, as, for instance, for the appointment of special committees from time to time, and it seems to me that, with that exception, gentlemen, we should vote for these resolutions, because it places upon the Directors the responsibility which they have requested and which belongs to them by right of their office (applause), carefully to consider and report upon the proposition in connection with the letter-ballot, and leaves the decision where it should finally rest, not with the few members here present, but with the membership throughout the length and breadth of this land. (Applause.)

FREDERICK BROOKS, M. Am. Soc. C. E.—Mr. President, a letter from Professor Swain was read yesterday, making some statements with regard to action taken in Boston; and it was introduced with an expression of doubt as to whether any of the gentlemen concerned in the Boston meeting are here.

I am sorry that there is but a small representation from Boston here; but I was myself present at the beginning of the meeting that was held there a week ago on Monday (although I was obliged to leave before it was over); and I talked upon the subject with my friends there. As the discussion yesterday attached weight to the expressions of opinion already offered by our members, it is proper to state that in Boston there was at least some knowledge of both sides of the question. One gentleman who was quoted here as one of the eight surviving early members of the Society happened to be in Boston about ten days ago; and I had the pleasure of an extended conversation with him in which he mentioned several of the points which he has included in his letter; and the paragraph from Mr. Morison's address, as President in 1895, occurring in Mr. Corthell's letter which was read yesterday by the Secretary, was read at the meeting in Boston. Some of the votes in the Boston canvass were sent by mail by persons not present at the meeting, but there was an attendance of thirty at the meeting.

Let me say a word for myself before I sit down. I share the views so ably presented by the last speaker here. It seems to me that a great deal that was said yesterday was not germane to the real question. It does not seem to me essential to enquire just what is the quality of the different societies involved in this proposition; it is not a question of amalgamation with them or union with them. It is a question of quarters in New York; and I am profoundly impressed with the great desirability of our having friendly relations with the other engineering organizations which have been referred to. It is very desirable that this Society shall have their friendship and sympathy; also

that this Society shall have, as far as possible, its influence upon them and have them feel a regard for its ideals. I strongly hope that the resolutions which have been prepared by the Board of Direction will be passed; and I have firm faith that such gentlemen as will naturally be put in charge of business of this character will be able to overcome any moderate difficulties in the way of what I regard as a most desirable consummation. (Applause.)

Mr. Catt.—Mr. President, I only wish to take your time for a moment. It seems to me that some of the matter that has been presented to us to-day and yesterday afternoon was probably of the nature of setting up a straw man and then proceeding to knock it down.

Now, I have before me what purports to be the offer of Mr. Carnegie, and I find that in that offer the American Society of Civil Engineers is first mentioned, and that the Engineers' Club was last mentioned, and I do not believe that Mr. Carnegie intended us as an anti-climax. I believe he intended to place the American Society of Civil Engineers as the first among the bodies to which this gift was to be given.

Allow me to say, it is not necessary, of course, that I should say that I have the honor of being a member of the American Society of Civil Engineers, but I have the pleasure of being also a member of the Engineers' Club, and I think that both organizations are eminently able to take care of themselves, and, in their particular lines, are perfectly respectable and creditable. As to whether they should be united in a common building and a common association, as outlined by the gift, would be a serious question. It seems to me that we should approach this question in a somewhat different spirit than has been manifested by some of those who have taken part. The spirit and intent of this gift, as I understand it, is to promote the interest of the engineering profession throughout the country, not only of this Society, but of all other societies, and the profession in general. This Society is unquestionably the ranking Society in this country at the present time. That position, I think will be conceded by the other associations that are asked to join in this movement. I think that the other associations are willing to grant to this Society that position, and I think that our strong position that we hold here would make us, not the people that should be the draggers in this movement, but that we should be the active and earnest people to further the advancement of this project and find some satisfactory solution of the matter.

There are several things that, it seems to me, have been brought in here that really have no connection with this matter. For instance, the Engineers' Club is not the dominant factor here. I think the American Society of Civil Engineers, in the end, will have just as much to say, as to what is to be done with this gift, as any other association. I believe that they will be the dominant force in this

Discussion on Joint Engineering Building (continued).

movement, if they take hold of it in a right manner, and if it is ill-advised to have the Engineers' Club in the same building under an undivided interest, that matter can be arranged for and carefully taken care of. It does not seem to me that it is absolutely essential that the property, even on Thirty-ninth Street, should be made a part of this project. I do not see any mention in the proposed donation that the property on Thirty-ninth Street shall be a part of the project. It may be better, and on investigation prove to be very much better, to have the united building alongside of the present building of the American Society of Civil Engineers. That matter has yet to be determined.

I do not think we should, in any case, take the position that we are either to rule this thing or do nothing, that it must be all our way or not at all; or that we will be like the little girl in the neighbor's yard, that if we cannot have it all our own way, we will take our rag dolls and go home. That is not the spirit in which we should approach this question.

In the matter of the other societies, I think in their several lines, they are as capable and as representative a body of men as we are. They do not cover as broad a field, to be sure, and I think most of them recognize that that is the fact. At the same time, if I were a member of those societies, which I am not, as I am a member of this, and this Society refrained from entering into an earnest endeavor to reach a solution of this problem which would allow us to unite, I would organize a society independent of this society which I would call The Institute of Engineers, and I would invite 250 members of each of the societies of the best, to come to it, and I would make the restrictions higher than those of the American Society of Civil Engineers, and twenty-five years from now it would be the ranking society of this country.

Take as an illustration: I happen to have pretty intimate relations with a good many of the members of these other societies, and I assure you that while they are young, there is not a brighter body of men anywhere than those that compose the Institute of Electrical Engineers. Twenty-five years from now they will be one of the strongest societies in this country, whether we join with them or not. It is as certain as that the time will roll by.

I am very much in favor of leaving this matter with the Board of Direction. I think that this resolution should be adopted, and that they should be given whatever time is necessary to bring the matter to a satisfactory solution. If it is found advisable to separate the common interests from the Engineers' Club, that should be done. Personally, I am in favor of it. I should think the club should have its independent existence entirely apart from the societies.

If it is found advisable that the property selected on Thirty-

ninth Street is not entirely satisfactory, I do not see why the Board of Direction cannot remedy this matter. We are not absolutely committed to it, nor is any one else, so far as I know, except possibly the people who were instrumental in securing the option.

For my part I would be in favor of saying to the donor, we thank you, and we will give to this matter such care and consideration that will find a satisfactory solution. I would say to the other societies, we will join you in this matter to the best of our ability to work out a solution of this matter that shall be to the best advantage of the engineering profession. And I would say to the Engineers' Club, we want to join with you in this matter to the best interests of us all, and then I would go forward, sure that this Society could not be injured by any friendly affiliation with the associated societies. (Applause.)

R. W. Lesley, Assoc. Am. Soc. C. E.—Mr. Chairman, the matter of the resolution seems to me to require possibly one small addition. The Committee of the Board, as I understand it, is limited in its decision as to the question of suitable apartments, or suitable quarters. It seems to me that some amplification of that might be added so that it might cover such facilities, both as to terms and as to regulation. In other words, the question is not merely whether the house suits us. It might suit us very well, but can we pay the rent? That is quite another question. And next, there might be regulations restricting us in our action, which is quite another serious problem. Therefore, it seems to me that some amendment of that might be proposed, simply broadening out that particular clause which would give our committee or our Board of Direction a little further power than is given under the wording of the resolution itself.

As to the question of time, it would seem that in all of our proceedings, in the appointment of every important committee and every important report, there has always been accorded a certain time for consideration and a certain term of notice. It would seem to me that this matter is either one that is good enough to keep or that it will not keep. If it will keep we want it; if it will not keep we don't want it, and therefore it does not seem to me that anything would be injured by giving it the proper consideration that those proceedings have in the general body of this Society.

One more point and I am done. This whole question seems to me to remind one very much of what we read of the debates in the constitutional convention of the United States. A number of States, a number of engineering societies; a number of States with their governments, their treasuries, their legislatures and all of their organization, and that is the case with these societies. It is now proposed to make a United States of Engineering; that can be done as it was with the United States of America. There is a President and

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there are rules and regulations governing all, but the rights of each State are preserved, and each State is independent. Each State is self-contained. Louisiana has the law of France, we have the law of England, but each State has its rights, its powers and its regulations, and yet they are all subservient to the general regulations of a general body. It would therefore seem to me that by widening the power of our Committee some regulations might be introduced in the body that is to govern or in the organization that is to control this building, making it not an affiliation of engineers, but a building for engineers—a United States of Engineering--and under that provision it would be perfectly possible to have a regulation in the voting for the board members like we have for Congressmen; it would be perfectly possible to have a regulation by trustees elected by property rights as we have Senators; and with that thought and with that idea that could be carried out in this case. We might all arrive at a conclusion by which the rights of all of the societies, and all their powers and all their privileges could be maintained, and still have what is proposed here, and be well regulated and well governed, and with all the interests subserved. (Applause.)

MR. HARROD.—Mr. President, if the gentleman who has just spoken will put his first suggestion in the shape of a resolution I will be very glad to second it. It occurred to me, soon after the reading of those resolutions, that it would be well to entrust the Board of Direction with larger scope, larger authority than seems to be written in them, to give them the opportunity, not only of determining the matter as to the question of accommodation—and the resolution seems to be confined to that—but to give them the authority not only to consider that, but to enter into conference and make their suggestions so as to open the subject wide in order to see if there is any line which is just to this Society and that will lead to final success. Then let their report cover not only the question of accommodation, with arguments *pro* and *con*, but let it cover the whole question.

MR. LESLEY.—If Mr. Harrod will prepare that resolution—he has given the subject more thought than I have—I would like to have you prepare that resolution if you will do it?

MR. HARROD.—Well, I should like to see the scope of the duties entrusted to the Board of Direction enlarged.

THE PRESIDENT.—Major Harrod, will you and Mr. Lesley prepare that amendment?

MR. LESLEY.—Yes, sir.

MR. CHARLES HANSEL.—Here I have it all prepared. (Laughter.)

MR. HARROD.—I don't think this exactly meets the point that I have in mind.

MR. HANSEL.—Well, then, I will offer this afterward.

MR. SEAMAN.—Mr. President, I have been very forcibly and very

favorably impressed, as I think has every one present, with the words of Col. Haines, and with the words of Mr. Catt, and I would like to say that I have, from the beginning, been heartily in favor of a closer association of the national engineering societies if it is practicable or if it can be made practicable, but I think it is important to demonstrate its practicability in every important detail before we jeopardize the ownership of approximately a quarter of a million of dollars and a home which we have established after long years of patience. It is with that anxiety, with a jealous guarding of that home that some of us have been very seriously worried for fear the control of our own property and of our own affairs would pass to the hands of others, and that fear is born of the experience of the past few weeks.

Mr. Carnegie has sent us a most generous offer, and the offer has never reached the Society in the shape in which it was sent. The letter containing the offer and everything it contained has been, it seems to me, coralled by the Engineers' Realty Company, and if I may so express it, it has been tied up in a little plot on Thirty-ninth Street where it looks to me as though they would erect a building for the four National Engineering Societies, and have an entrance to that building over private property owned by the Engineers' Realty Company and used by a social club. That is a pretty strong statement, gentlemen, but it is only reached after looking at the matter very fairly.

Why was the property on Thirty-ninth Street selected, and by whom was it selected? It was selected by the members of the Engineers' Realty Company after they had purchased their property on Fortieth Street. It was selected right back of their property on Fortieth Street. It is proposed to put this magnificent building on a back street, when we, worth approximately a quarter of a million dollars, can afford a better site. The entrance to that building is to be through property owned by the Engineers' Realty Company, and to that extent under their control.

With our present financial standing, with the present financial standing of the American Society of Mechanical Engineers, with the prospective standing of the Institute of Electrical Engineers, why should not the building be located on a more favorable site, such as Fortieth Street? Has the Engineers' Realty Company offered to contribute its site, already bought on Fortieth Street, to the general project? I have not heard of any such proposition. In fact, it is only a week ago that a member of the Engineers' Realty Company said to me, "Mr. Seaman, you will take it as it is, or you won't take it at all." I replied, "Mr. ———, I am ready to vote on that to-morrow."

Those of us who chanced to attend the meeting of May 7th in our own Society house felt that the Engineers' Club did have the control. When Mr. Catt says we control our own affairs, he forgets that we are

Discussion on Joint Engineering Building (continued).

only three in fifteen, and that the Electrical Engineers and that the Mechanical Engineers are, by their very nature, more commercial in their organization than we possibly can be.

It seemed to me that the presentation at that meeting came almost entirely from the Engineers' Club and its affiliations, and when Mr. North arose to ask a few pertinent questions I was dumbfounded when a member then moved that the meeting adjourn. It was after that that Mr. Oberlin Smith arose and said that we should hear from the Civil Engineers, since we had not heard from them, but after a very little more discussion, some resolutions, which had been prepared in advance, were offered, and here is the tenor of them:

"At a meeting held on the evening of May 7th, 1903, in the house of the American Society of Civil Engineers, attended by official representatives of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers and the Engineers' Club of New York City, it was

* * * * * * * * *

"*Resolved*, that we hereby tender to Mr. Andrew Carnegie our hearty thanks for the trust he has imposed upon us, which we accept with a full realization of its responsibilities, and will endeavor to carry out with all possible dispatch and effectiveness, thereby to hasten the day when engineers shall"——

I haven't the last of it, but, at any rate, that is the acceptance of that proposition in the house of the American Society of Civil Engineers, with the Civil Engineers speaking hardly a word.

Why, gentlemen, it was only for one purpose. Some of us were very much concerned, and quoting from a letter, which I wrote at the request of *Engineering News:*

"It was only then that the members of the American Society of Civil Engineers, who happened to be informally present, awakened to the responsibility they were asked to assume, and it was through their outspoken objection that the message and resolutions were finally modified.

"The experience thus gained does not demonstrate the advisability of placing the management of any of the Society's affairs in committees composed of outside interests."

Mr. Haines.—Excuse me, but my only object in rising is the hope that we may expedite the determination of this question, and as there has been some discussion about the manner or the time in which the proposed report of the directors shall be submitted for letter-ballot, I would offer this resolution:

"It is the sense of this meeting that the letter-ballot called for in the resolutions should be presented to the Society with the usual sixty days' notice and opportunity for discussion in business meeting."

Mr. Hansel.—I second that motion.

The President.—There is a motion before the meeting. Is there any discussion?

Mr. Croes.—The question of the usual sixty days' notice to which Colonel Haines refers is, I suppose, the regulation according to the Constitution that matters which are to come up at the Annual Meeting shall be presented with sixty days' notice and discussed at the Annual Meeting and then presented for ballot. I do not know of any other provision for the usual sixty days' notice for the taking of a letter-ballot and the discussion by the Society before the letter-ballot is presented, but only after a general business meeting, of which there are two, the Annual Convention and the Annual Meeting. Does Col. Haines mean to refer to the constitutional provision regarding the annual meetings in that case at which discussion takes place?

Mr. Haines.—Mr. President, I admit that I left it open intentionally. I desired to get the sense of this meeting as to whether they would prefer to postpone this whole matter, to delay it until it should come up at the Annual Meeting, or whether it might come up for discussion at our usual monthly meetings. In the latter case it would somewhat expedite the consideration of the report and it being spread broadcast through the country to our membership. If it is to be deferred to an Annual Business Meeting, why that delays action upon it, and I purposely left that open. I thought there was an opportunity here to discuss that particular point if the resolution should meet with favor in this body.

Mr. Smith.—Mr. President, it is very much to be deprecated that this whole matter should be left open until the Annual Meeting, and then have another delay in getting ready the ballots and sending out the notices, and then sixty days after for balloting. That puts the whole thing off nearly a year. It seems to me that with the feeling of the other societies, it could not possibly be delayed that long, and we would be simply left out. Perhaps that is what some of us want; some do want to be left out and some do not; that is the very point that the membership ought to decide, whether this Society is going to be left out from this affiliation with what is going to be a great engineering center in New York, with other societies all around, and clubs, and architects' offices, a general headquarters of engineering for the United States and Canada. Any idea of putting it off for about a year before saying whether we will or will not accept that gift probably means our being left out. If this convention wants to take such responsibility and give the membership at large no opportunity to decide the question, so be it, but our Board of Direction should be able to take action, and within the next two or three months settle on something so that the letter-ballot can go out soon. I do not, therefore, favor this sixty days' waiting after the Board of Direction shall satisfy themselves.

Mr. Davison.—Mr. President, I hope that the resolution offered by Col. Haines will be adopted, whether it takes a year or two years or five

Discussion on Joint Engineering Building (continued).

years. I consider that this matter, as expressed yesterday, is one of the most important questions that has ever come before this Society, and I think that we have all gained a great deal of good by being here these two days to listen to the arguments that have been already presented. I feel that all the arguments will not be presented at this meeting, and I think that those who are absent and cannot be reached even by the voice of this meeting should be given all the information that it is possible to give them before they are asked to cast their votes.

As to what this delay may mean to this Society or to the other societies, or to Mr. Carnegie, it is about like this: I understand that the other societies are going ahead with this project, or at any rate, we can come in or stay out as we see fit. I think they will prefer to have us come in, even if we should delay coming in for a year or two, so that it does not affect them seriously. They will have their home whether we come in or not.

As to the effect upon Mr. Carnegie, I would say that I happen to live in a section of the country where Mr. Carnegie's gifts have been very numerous, and the history of those gifts is that they have not always been accepted with the enthusiasm that they seemed to deserve. Years have elapsed before final acceptance in at least two cases that I know of, and there is a gift at present hanging over the heads of the people of that community, and it has been so hanging for a number of years (laughter). Mr. Carnegie is a persistent giver (laughter), and when he makes an offer, he does not expect an answer at once, but desires to have it weighed carefully.

So that I am satisfied that we are not losing our share in this gift by waiting even a year, if we so desire; it will certainly not hurt Mr. Carnegie's feelings if he knows we are carefully considering the matter. and I believe in so considering it. While I do not agree with all the remarks that have been made by the other members, I think it is perfectly proper that we should have all the points, whether or not they are agreeable to us or to others; let us have them all; it may influence us in the right way.

I feel that a great deal has been said that might have been left unsaid, and yet those remarks have certainly educated me. Doubtless some of the members of the Society who are not here to-day may desire to speak upon this subject, and I think they should be given an opportunity, and I believe the first opportunity that can be given them now is at the Annual Meeting next winter, and I think the resolutions should provide, and I believe it is the intention to provide, that there shall be at least one more general discussion of this subject. I think it is absolutely necessary that we should have it. (Applause.)

MR. BROOKS.—Mr. President, if I understand correctly, the resolution of Mr. Haines is before the house; and if so, it is fair to ask what the significance of it is. The opinion has been expressed that the

"business meeting" referred to in his resolution means such meetings as are held annually, the Annual Meeting and Annual Convention, of which there are only two in a year. There is another interpretation possible, Mr. Haines says, to wit, that it refers to monthly meetings of the Society. I would like to be informed as to that.

Mr. Croes.—Will Colonel Haines accept an amendment to that, which is that this resolution be presented for discussion at a time not less than sixty days before the next Annual Meeting? That would give time for discussion. I doubt very much whether, during the summer season, the committee which has charge of this matter could obtain all the information that it wants and formulate its ideas, and we do not want to delay it. Nobody wants to delay it to an unreasonable time. I wish to see the matter come before the Society fully and be fully discussed, and to vote with the majority, although I may vote against it at the time. Still the decision of the majority will govern me, but if some little time is given, a little time within which to present this question, say, so that the usual notice before the Annual Meeting can be given, and not later than that.

Oscar Lowinson, Assoc. M. Am. Soc. C. E.—Why not entrust that to the Board?

Mr. Croes.—Well, the Board might lay it over. If you want to make the Board act promptly, give them a limit of time and make that limit of time the sixty days before the Annual Meeting.

Mr. Haines.—Mr. President, as you see, it was evidently my purpose in offering this resolution to take advantage of what has so far been developed in this discussion, and I think you will agree with me in the opinion that it has developed the fact that we know very little about the matter, and that a matter of this grave importance should not be acted upon hastily and with insufficient information.

Now, I think, from the discussion on my resolution, it is plain that the gentlemen here present are of the opinion that there should be further time given for a consideration of this matter before any letter-ballots should be taken. I offer that resolution, not with any purpose to defeat the wishes of the majority of the membership of this Society, but with the purpose of obtaining that opinion and to have it carefully and intelligently rendered. For that purpose, I thought we should have at least sixty days after the report of the Board had been presented, in order to think this matter over before any vote was taken on it.

I will say that I purposely refrained from saying whether the sixty days' notice should be anterior to a monthly business meeting or to the Annual Business Meeting, and it is now quite open to any gentleman here present to offer an amendment that the business meeting shall be the Annual Business Meeting. Now, if that amendment is offered and a vote taken on it, and it is decided that it shall be at the Annual

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Business Meeting, then that amendment would be incorporated in my resolution, and my resolution can go before you with that amendment. If that amendment is voted down then it will evidently be the sense of this meeting that the delay shall only be until a monthly business meeting. I hope the gentlemen that desire to see this matter referred to the Annual Business Meeting will offer an amendment to that effect.

MR. SMITH.—Mr. President, I hope that Col. Haines' motion will stand, although sixty days is rather long to wait for the letter-ballot, as it is better than to put it off until the Annual Meeting. If the amendment is voted on to put it off until that time and then have sixty or ninety days' delay after that——

MR. CROES.—The Constitution requires sixty days.

MR. SMITH.—But I hope that will date from one of the monthly meetings, as Mr. Haines intended it.

MR. HAINES.—I did not say that.

MR. SMITH.—Well, he evidently left it open, so that it might be from any meeting, a monthly or an Annual Meeting. That leaves it in the hands of the Board of Direction, and that is what I had in mind. They would know much more than we do about it. They live in New York, and are able men, coming in close touch with the other Societies. Leave it to them to hurry up the thing and get it in proper shape. What is the use of this small convention now attempting to put the matter off until the Annual Meeting? Leave the thing as Mr. Haines has put it, and that will give the chance to have the Board of Direction act quickly on the matter, and, if they can present it at a monthly meeting, do so.

There is one point I have to urge against what Mr. Davison has said, that it would be just as well to accept Mr. Carnegie's gift or our share of it a year or two hence or at some other time as well as now. There is one important point that he did not take into consideration. If the other societies, to whom Mr. Carnegie is going to give the thing if we do not go into it, should decide to go ahead and make their building plans, and actually start their building, or, at any rate, get an architect and have the thing worked out before we do anything, then, if we want to come in, we have got to take those plans as they have planned them, and we have got to take a part of a building that we did not plan ourselves. We want a finger in this pie, and we want a big finger in it. If a big building is to be put up, which is partly for us, we want to have a big share in the planning of that building, but if we delay and then finally come in, we have got to take part of a building, in the design of which we have had no share.

MR. CROES.—I want to make one remark in reply to Mr. Smith. He spoke of the Board of Direction living in the City of New York. They do not live in the City of New York; they live all over the coun-

try from Maine to California, and from Canada to New Orleans, and there are thirty of them, and seven of them constitute a quorum Seven members could be got together in New York and constitute a quorum and bind the Board of Direction in a way that we don't want to have done by a small number of men. We want to have a full discussion by the full Board of Direction and have the action of a majority of them.

THE SECRETARY.—For the sake of the record I should like to say that five constitute a quorum.

MR. CROES.—Five, according to the Constitution, are a quorum, and five members can bind the Board. Now, I do not want to reveal any secrets, or anything, but I know there is one member of the Board of Direction, when this matter first came before them at an informal meeting, and his attention was called to the constitutional provisions which seemed to require delay, who said that this was a case of the application of the old saying, "What is the Constitution among friends?" And he wanted to pass it right off. I don't know how the Board of Direction stands; nobody knows; but they all want to know something about it, and they cannot do it in a limited time, and they must have plenty of time to consider it before they can present it to the Society, or present the report of any committee that can be made. We have got to have a majority of the Board of Direction, I think, and certainly the laws of the State of New York require that in any matter involving real estate, in matters relating to the purchase and sale of property and the disposition of it, it can only be determined by a vote of two-thirds of the Board of Direction, such two-thirds being all present and voting. We cannot limit the time in that way, but we can, I think, do it within a time so as to bring it up at the next Annual Meeting.

I do not want to see any delay; I want the matter brought thoroughly before the Society and discussed, but I do not want to put it in the hands of five men in the City of New York to accept or to make a proposition to present to this Society for consideration—a majority out of five men who live in the City of New York, if there are five directors who live there.

MR. DAVISON.—I just wish to reply to Mr. Smith, and to say to him that there is no danger, in my mind, of the other societies going ahead and planning this building so long as this Society courteously asks the time, say six or eight months in which to make up its mind as to coming in, and I am satisfied that Mr. Carnegie will look at it in the same light, and will not care to have the societies go ahead too hastily.

MR. HANSEL.—Mr. President, it seems that the fear of some is that the option on certain land on Thirty-ninth Street may expire. I would suggest that there is another location in the vicinity of Fifty-

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seventh Street that perhaps could be gotten. I do not understand that there is any hurry about this thing at all.

Engineers are sometimes held out of the command of affairs because they are said to be lacking in executive ability, and I feel that organization is the thing that has made this Society. Now, to hazard our organization by giving up our voice in an organization seems to be a very foolish thing to do. I do not understand that anything that is said here to-day is to decide the acceptance or declining of the offer. It is only a talk to get at the views of the members, and if it is to be decided to-day, I certainly would vote against accepting the offer as it is now made.

I am unfortunate in that I am also a member of the Engineers' Club (laughter); it seems that I am unfortunate, although I am happy to say that I am a member of that Club. Some engineers are afraid that they are on the side of commercial engineering. I am, and I am trying to get stronger on that side every day (laughter). If an engineer has not anything to sell he does not belong to our Society, because he sells his talent and his skill, if he has anything at all. All engineers are eligible to our Society. I don't say that all who say they are engineers are, but all engineers are eligible to the American Society of Civil Engineers.

The American Society of Civil Engineers, as I understand it, is called civil engineers simply because they are an independent association and are not in the service of the Federal Government, and if they are to preserve their independence, it seems to me that, under any conditions of the acceptance of this offer, they should have their home as it is now. I certainly would never consent to give up my home to share in a hotel, and I want to ask if it is in order to suggest a specific time for a special meeting, say, sixty or ninety or one hundred and twenty days, or ten months, if you please, from now—a specific time for a special meeting. As I understand it, there are only two opportunities for a business meeting, at the Annual Meeting and at the Annual Convention, and it seems to me a special meeting should be called for the consideration of a subject that is, to my mind, exceedingly important. (Applause.)

Mr. Smith.—I would like to ask a question of the Secretary which is pertinent. I don't think a great many of us here know about our own real estate. It has been stated that it was worth about a quarter of a million, and probably it is. I want to ask the Secretary whether it is property that can easily be disposed of, on account of the nature of the building and the neighborhood, and what his estimate is of the probable value that we could get for it if we sold it.

The Secretary.—Mr. President, recent inquiry as to the value of property in the immediate vicinity of the Society House leads me to suppose that it is worth about $70 000 for a 25-ft. lot, and that you

cannot get it for $100 000; that is about all I can say as to the value of the land.

MR. SMITH.—Well, our 50-ft. lot would be worth about $200 000?

THE SECRETARY.—We paid $40 000 per lot, or $80 000 for the 50 ft. If the present building were not on those lots I believe they could be sold for $150 000 or $160 000 at any time.

MR. SEAMAN.—What did the building cost?

THE SECRETARY.—The building itself, about $90 000, I think, as near as I can remember it.

MR. SMITH.—Has there been any estimate as to how much it could be sold for to remain as it is, for other purposes, public purposes?

THE SECRETARY.—That is a difficult matter. You would have to find a customer for it, find somebody who would fit into it. As a matter of fact, it seems to me that that building would lend itself very well indeed to almost any not too large club. It is so arranged that club kitchens could be installed; there is ample space for that in our present storage room, and the larger rooms for dining rooms, and all that sort of thing, and if you leave out the question of sleeping apartments, which almost all New York clubs are coming to now, it would be an ideal small clubhouse, although built entirely for the purposes of our Society.

MR. SMITH.—Would it work in connection with art schools or something of that kind? We seem to be in an artistic neighborhood. Could it be used for any artistic purposes?

THE SECRETARY.—I should think it might; I can see no reason why not. It has good light.

MR. HANSEL.—Mr. President, I asked if it was in order to name a special day or a day for a special meeting to consider this subject.

THE PRESIDENT.—That may be offered as an amendment to the resolution which Mr. Haines has proposed.

MR. HANSEL.—Well, I did not know but that if it was offered it would conflict with the Constitution. I understand that any new business has to come up at either the Annual Meeting or the Annual Convention, and I ask for information, Mr. President.

THE PRESIDENT.—We are advised by counsel that it is perfectly legal for the Board of Direction or for this Convention to accept or reject the Carnegie proposition if that action was thought wise. It is perfectly legal for the Convention or for the Board at any meeting to do that.

MR. HANSEL.—Yes, but that is not the point I was after. Is it legal, under our Constitution, to appoint a day for a special meeting of the Society to consider this question?

THE SECRETARY.—There is nothing in the Constitution to prevent that, so far as I know.

Discussion on Joint Engineering Building (continued).

MR. DAVISON.—I would amend Col. Haines' resolution by inserting in it the words "the Annual Meeting" of the Society.

EMIL SWENSSON, M. Am. Soc. C. E.—I second the motion.

THE PRESIDENT.—The Secretary will read the resolution.

THE SECRETARY.—It is the sense of this meeting that the letter-ballot called for in the resolutions should be presented to the Society with the usual sixty days' notice, and opportunity for discussion in business meeting.

THE PRESIDENT.—The Chair understands that Mr. Haines offers that as an amendment to the resolution which is before the meeting. That is the only way it can have consideration.

MR. HAINES.—Yes, sir.

MR. CATT.—I will second Mr. Haines' motion.

THE PRESIDENT—And Mr. Davison's amendment to this is what?

THE SECRETARY.—That it is the sense of this meeting that the letter-ballot called for in the resolutions should be presented to the Society with the usual sixty days' notice and opportunity for discussion at the next Annual Meeting.

MR. HARROD.—I second that.

THE PRESIDENT.—That is Mr. Haines' resolution as amended by an amendment offered by Mr. Davison. Are there any remarks?

MR. DAVISON.—I would suggest the Annual Meeting, for the reason that any other meeting would generally be attended by the local members in New York alone, while the Annual Meeting will be attended by the members at large, and I am satisfied, from the interest displayed in this meeting, that we will have a rousing old meeting if it should go through.

MR. SMITH.—I understand that this vote now is on the amendment to Mr. Haines' resolution, and I certainly hope it will not go through because it takes it out of the power of the Board to act quickly if they want to.

(Cries of "Question"!)

THE PRESIDENT.—The mction is on the provision that the matter will be considered at the Annual Meeting of the Society.

The motion, being put, was carried.

THE PRESIDENT.—Now the question before the meeting is the resolution offered by Col. Haines as amended. All in favor of Col. Haines' amendment as read and amended, say aye.

The motion was carried.

THE PRESIDENT.—The question is now on the resolutions offered by the Board as amended by Mr. Haines' resolution?

MR. HARROD.—I would like to offer an amendment to the resolutions of the Board. There are six resolutions submitted by the Board, and I would like to offer this amendment to the third resolution. It now reads:

"*Resolved*, that the Board of Direction be authorized to ascertain whether suitable accommodations can be obtained for the Society in the proposed new building, with provision for future needs."

I offer as an amendment to add to that:

"And also to make such investigations and hold such conferences as may bear upon the advisability of the acceptance of Mr. Carnegie's proposition by this Society."

That is simply to enlarge the scope of the work of the Board of Direction. If that is passed it makes a slight change necessary in the fifth resolution that reads:

"*Resolved*, that the Board of Direction be requested, provided it is satisfied that suitable accommodations can be obtained," and I would amend it by inserting the words, "and that the acceptance of the proposition is otherwise practicable."

MR. SWENSSON.—I second that amendment.

The motion, being put, was carried.

THE PRESIDENT.—The question is now on the resolutions offered by the Board as amended.

The motion, being put to vote, was carried.*

THE PRESIDENT.—The resolutions are adopted.

MR. HANSEL.—Mr. President, I understand that the Society, as the American Society of Civil Engineers, has never acknowledged to Mr. Carnegie the receipt of the offer which he has tendered this Association. If so, I desire to offer this resolution:

Resolution of thanks to Mr. Carnegie.

"*Resolved*, that the American Society of Civil Engineers acknowledge the offer from Mr. Carnegie, and thank him sincerely for the opportunity, and advise him at the same time of the action to-day, and that the object of this delay is to determine and consider every feature of the situation carefully before deciding the matter."

MR. SWENSSON.—I second the motion.

The motion, being put to vote, was carried.

Announcements as to Programme.

THE SECRETARY.—Mr. President, the Chairman of the Local Committee, Mr. Ludlow, wishes to make some announcements as to the programme.

MR. LUDLOW.—Mr. President, Ladies and Gentlemen: I wish to announce in reference to the programme of entertainment for to-day and to-morrow, and some other incidental matters, that this afternoon, as you will notice by the programme, our purpose is to have a trolley ride covering the most interesting portions of the city, which will require about eighty minutes, including a ride to Riverside Park and one other suburban line, and this trolley ride will end at the golf grounds, where preparations for a golf tournament by engineers is under way, and when I say it is by engineers, it means that it will outclass any championship games that have been held in Asheville for a number of years, doubtless. Mr. Hunt has the matter in charge, and anyone who desires to participate in this tournament this afternoon will report

*The resolutions as adopted may be found on page 199.

Announcements (continued).

either to Mr. Hunt or to Mr. Guild, of the Local Committee, who are making the entries and arranging the handicaps, etc.

Immediately after the adjournment of this morning's session, there is a photographer here who is very enterprising and very capable, and he tells me that he has taken all sorts of group pictures of distinguished bodies that have visited Asheville, but he has never had an opportunity of getting a picture of a number of engineers, and he is particularly anxious that he be afforded an opportunity.

A MEMBER.—Is this another question of affiliation?

MR. LUDLOW.—And while none of us care particularly about seeing our names in print, or our faces on cardboard, I would ask that immediately after adjournment just by way of courtesy to this photographer, we gather on the green on the hillside just in front of the hotel and permit him to perpetuate with the camera a memento of the occasion of this convention in Asheville.

A MEMBER.—What is the time of the trolley ride, sir?

MR. LUDLOW.—Three o'clock is the hour stated, and we will adhere to that as nearly as possible.

We have a card, handed in yesterday, which I placed in the hands of the Secretary, from the Asheville Club, a social organization, which very kindly tenders a card to all the members of the Society and guests, and the courtesies of the club house for a period of fifteen days.

The courtesies of the Golf Club have also been extended, which I believe was announced yesterday, by our Secretary, from the platform.

As to the matters for to-morrow, I think that everything is quite fully stated on the printed programme. To-morrow evening, as we return from Overlook Mountain, we will have some entertainment here at the hotel.

On Friday, as you will note by the programme, we have booked the ride to Biltmore. For this drive we have arranged with the liveryman—they have a liverymen's association here, and they have agreed to provide carriages to accommodate the entire party, all nice vehicles that will be comfortable, as well as pleasant to see, and they will be here at some hour on Friday morning to arrange the matter. I think the hour for the Biltmore drive will be determined largely by the condition of the weather on Friday morning, if we find that it is practicable and no other conflicting engagements have been made. For this occasion it has been arranged with the local liveryman that carriages will be furnished to hold as many as they will accommodate comfortably, three, four, or half a dozen, and that instead of each carriage being paid for separately, there will be tickets furnished, and they will be on sale by to-morrow at $1 per person, which will include the carriage drive through Biltmore and Victoria Park, embracing a drive of about four or five hours.

I would say in passing, that the Local Committee would like very much to have included this in the provisions they have made for your pleasure, but the Secretary says that the members of the American Society of Civil Engineers don't like to have things paid for for them; they like, at least, to think they are doing things themselves (applause and laughter), so we have compromised the matter and will let you pay for your tickets for the Biltmore drive.

THE SECRETARY.—Mr. President, I would like to announce that through the kindness of Herbert M. Wilson, M. Am. Soc. C. E., geological sheets of Asheville and the vicinity are in the office of the Secretary and may be had upon application. They will doubtless be found of interest to our members in traveling around here.

MR. LUDLOW.—I have one more announcement to make. The Southern Railway ticket agent has just come to see me as to the return trips and the accommodations for sleepers, etc. It distresses us to think about return trips so early, but perhaps for convenience and comfort it had better be mentioned. I have arranged with the Division Passenger Agent that he be here himself, or have a representative here at the hotel to-morrow evening at nine o'clock to make bookings for the return trip on the Pullman service, and he is anxious to get this information as early as possible, so as to furnish plenty of cars and accommodations. He states in confidence that he will endeavor to furnish every one with lower berths and drawing-room space, so any of you who have fixed the time of your departure by to-morrow night can see the ticket agent and secure your reservations.

Adjourned.

EXCURSIONS AND ENTERTAINMENTS DURING THE THIRTY-FIFTH ANNUAL CONVENTION.

The arrangements for the Convention were in the hands of the following Committees:

Committee of the Board of Direction:

J. JAMES R. CROES, *Chairman;*

GEORGE H. PEGRAM, CHAS. WARREN HUNT.

Committee of Local Members:

J. L. LUDLOW, *Chairman;*

WILLIAM CAIN,
WILBUR F. FOSTER,
GEORGE W. FRANK,
J. C. GUILD,
J. N. HAZLEHURST,
W. B. W. HOWE,
W. A. LELAND,
J. IMBRIE MILLER,
J. A. MONTGOMERY,
E. T. D. MYERS,
ARTHUR PEW,
GEORGE O. TENNEY,
NISBET WINGFIELD.

By courtesy of the Pennsylvania and the Southern Railroads, the members of the Society and their guests were accommodated in special cars from New York to Washington, and in a special train from Washington to Asheville. The party left New York at 11 A. M. on Monday, June 8th, and arrived at Asheville on the following day at 9 A. M.

The Trunk Line, Southeastern, and Central Passenger Associations, granted a rate of one first-class fare, plus 25 cents, for the round trip to and from Asheville, from all points in their territories.

In the afternoon of Wednesday, June 10th, by the courtesy of the Asheville Electric Company, a trolley trip around Asheville was made by a large party of members and guests. The trip terminated at the Swannanoa Country Club, where, by courtesy of the club, a special golf competition was held.

On Wednesday evening the members and guests of the Society were received by the Hon. Charles B. Aycock, Governor of North Carolina.

On Thursday afternoon, by invitation of Richard S. Howland, Esq., President of the Asheville and Craggy Mountain Railroad Company, the members and guests visited Overlook Park, on Sunset Mountain, where they spent the afternoon and enjoyed a "Barbecue" prepared especially for them. The features of the Asheville and Craggy Mountain Electric Railroad were described in a pamphlet by R. H. Tingley, M. Am. Soc. C. E., who built the road up the mountain.

In the evening a concert and Southern Plantation Entertainment was enjoyed by a large audience.

On Friday a large party took carriages and drove through the grounds of "Biltmore," the estate of George W. Vanderbilt, Esq.

THE ATTENDANCE AT THE THIRTY-FIFTH ANNUAL CONVENTION.

The following 122 members were in attendance:

Allen, C. H.....New York City
Atkinson, J. B.....Earlington, Ky.

Bacon, J. W..... ...Danbury, Conn.
Baird, Howard C....Phœnixville, Pa.
Barnsley, George T....Oakmont, Pa.
Betts, E. E.....Chattanooga, Tenn.
Braune, G. M.....Birmingham, Ala.
Brenneke, W. G.....St. Louis, Mo.
Breuchaud, J.....Yonkers, N. Y.
Brooks, Fred.....Boston, Mass.

Cain, William.....Chapel Hill, N. C.
Carson, W. W.....Knoxville, Tenn.
Catt, George W.....New York City
Chapin, L. E.....Canton, Ohio
Chester, J. N.....Pittsburg, Pa.
Clark, L. V.....Philadelphia, Pa.
Clayton, R. M.....Atlanta, Ga.
Condron, T. L... ..... Chicago, Ill.
Connor, E. H....Leavenworth, Kans.
Cooper, Samuel L....Yonkers, N. Y.
Crane, Albert S .....Chicago, Ill.
Croes, J. J. R.....New York City
Cummings, Robert A..Pittsburg, Pa.

Davis, Chas ... Allegheny, Pa.
Davison, George S.....Pittsburg, Pa.
Diebitsch, Emil.....New York City
Douglas, B..... Detroit, Mich.
Dyer, Arthur J.....Nashville, Tenn.

Ellis, John W... .Woonsocket, R. I.

Foster, E. H.....New York City
Francis, George B... New York City
Frank, George W. New London, N. C.

Gillespie, R. H.....New York City
Goodell, John M..... New York City
Grantham, Herbert T.,
Philadelphia, Pa.
Green, Bernard R. Washington, D. C.
Guild, J. C.....Chattanooga, Tenn.

Haines, H. S.....Detroit, Mich.
Hanna, John V.....St. Louis, Mo.
Hansel, Charles.....New York City
Harlow, J. Hayward, Jr.,
Conowingo, Md.
Harris, Van Alen,
San Juan, Porto Rico
Harrod, B. M.....New Orleans, La.
Hatt, W. K.....Washington, D. C.
Hermann, E. A..... .St. Louis, Mo.
Hider, Arthur .....Greenville, Miss.
Hinckley, J. F .....St. Louis, Mo.
Horton, Horace E.....Chicago, Ill.
Hotchkiss, C. W.....Chicago, Ill.
Howard, John Lewis...Boston, Mass.
Hunt, Chas. Warren..New York City
Hyde, Charles Gilman,
Harrisburg, Pa.

Jackson, J. M...Parkersburg, W. Va.
Johnson, A. L .....St. Louis, Mo.
Johnson, J. M.....Louisville, Ky.
Johnson, L. J.....Cambridge, Mass.
Judson, Wm. Pierson. Albany, N Y.
Juengst, H. F... .Birmingham, Ala.

Kendrick, J. W....Birmingham, Ala.
Kimball, Frank C...Knoxville, Tenn.
King, Paul S.....New York City
King, Wallace, Jr.....New York City

Lesley, R. W..... .Philadelphia, Pa.
Lowinson, O .....New York City
Lucas, E. W. Van C. Memphis, Tenn.
Ludlow, J. L.....Winston, N. C.

McCalla, R. C.....Tuscaloosa, Ala.
McDonald, Hunter..Nashville, Tenn.
McLain, L. R... St. Augustine, Fla.
McMinn, T. J.....New York City
Maltby, F. B.....Memphis, Tenn.
Maxwell, J. R.....Newark, Del.
Martin, William.....Bellevue, Pa.
Melvin, David N. Linoleumville, N. Y.
Miller, J. Imbrie.....Montreat, N. C.
Miller, Rudolph P....New York City
Modjeski, Ralph.....Chicago, Ill.

Montfort, R.....Louisville, Ky.
Montgomery, J. A.Birmingham, Ala.
Morris, Marshall.....Louisville, Ky.
Myers, E. T. D., Jr...Richmond, Va.
Myers, E. W.....Greensboro, N. C.

Nicholson, George B..Covington, Ky.
Noble, Alfred.....New York City.

Osborn, Frank C.....Cleveland, Ohio

Pegram, Geo. H.....New York City
Pew, Arthur.....Bolton, Ga.
Polk, Wm. Anderson..New York City
Pope, Macy S.....Boston, Mass.
Potter, H. W.....New York City
Pressey, H. A.....Washington, D. C.

Reed, W. Boardman..New York City
Riggs, M. J.....Toledo, Ohio
Ruggles, Charles A...New York City
Russell, S. Bent.....St. Louis, Mo.

Schaub, J. W.....Chicago, Ill.
Schneider, C. C.....Pencoyd, Pa.
Scofield, E. M.....Pittsburg, Pa.
Seaman, Henry B.....New York City
Shedd, Edward W..Providence, R. I.
Shedd, J. Herbert..Providence, R. I.
Shryock, Joseph G.Philadelphia, Pa.
Smith, Oberlin... .Bridgeton, N. J.
Snow, J. P.....Boston, Mass.
Swensson, Emil.....Pittsburg, Pa.

Thacher, Edwin.....New York City
Tillson, Geo. W.....Brooklyn, N. Y.
Tingley, R. H.....New York City
Trundle, H. H.....Leesburg, Va.

Van Horne, John G...New York City

Wadsworth, J. E.....New York City
Wagner, Samuel Tobias,
Philadelphia, Pa.
Wallace, J. F.....Chicago, Ill.
Warder, J. H.....Chicago, Ill.
Wegmann, E.....Katonah, N. Y.
Wiley, Wm. H..... New York City
Wilson, H. F., Jr..Birmingham, Ala.
Wilson, H. M.....Washington, D. C.
Winfree, P. B.....Lynchburg, Va.
Wingfield, Nisbet.....Augusta, Ga.
Wölfel, Paul L ....Philadelphia, Pa.
Worcester, J. R.....Boston, Mass.

The total registered attendance at the Convention was as follows:

Members of the Society, in all grades	122
Guests, including ladies	133
Total	255

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, September 2d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "An Experimental Study of the Resistances to the Flow of Water in Pipes," by Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E., will be presented for discussion. This paper was printed in *Proceedings* for May, 1903.

Wednesday, September 16th, 1903.—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Theory of Centrifugal Pumps and Fans; Analysis of their Action, with Suggestions for Designs," by Elmo G. Harris, M. Am. Soc. C. E. (printed in *Proceedings* for May, 1903); and "Tests of the Efficiency of Hoisting Tackle," by S. P. Mitchell, M. Am. Soc. C. E., printed in this number of *Proceedings*.

Wednesday, October 7th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership and ballots on the proposed amendment to the Constitution will be canvassed, and a paper by Francis Robert Johnson, M. Am. Soc. C. E., entitled "South African Irrigation," will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, October 21st, 1903.—8.30 P. M.—At this meeting two papers will be presented, as follows: "Some Railway Construction in Oklahoma," by A. G. Allan, Assoc. M. Am. Soc. C. E.; and "The Fatigue of Cement Products," by J. L. Van Ornum, M. Am. Soc. C. E. These papers are printed in this number of *Proceedings*.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed

frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches for members to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ACCESSIONS TO THE LIBRARY.

From May 13th to August 8th, 1903.

DONATIONS.*

TREATISE ON HYDRAULICS.

By Mansfield Merriman. Eighth Edition, Rewritten and Enlarged, Cloth, 9 x 6 ins., 8 + 585 pp., illus. New York, John Wiley & Sons. 1903. $5.00.

Since the publication of the first edition of this treatise, in 1889, many advances have been made in hydraulics. Some of these have been noted briefly in later editions, but to record and correlate them properly it has become necessary to rewrite and reset the book. The same plan of arrangement as in former editions has been followed, but two new chapters have been added, one on Hydraulic Instruments and Observations, which treats of the methods of measuring pressures and velocities, and another on Pumps and Pumping, in which the various machines for raising water are discussed from a hydraulic point of view. Many new examples and problems are given, and in these the author has endeavored, not only to simplify the theory of the subject, but also to illustrate the conditions of actual practice. Historical notes and references to hydraulic literature are presented with greater fullness than before. While the main purpose in rewriting the book has been to keep it abreast with modern progress, the attempt has also been made to present the subject more concisely and clearly than before, in order to advance the interests of thorough education and to promote sound engineering practice. The chapter headings are: Fundamental Data; Hydrostatics; Theoretical Hydraulics; Instruments and Observations; Flow through Orifices; Flow over Weirs; Flow through Tubes; Flow through Pipes; Flow in Conduits; Flow of Rivers; Water Supply and Water Power; Dynamic Pressure of Water; Water Wheels; Turbines; Naval Hydromechanics; Pumps and Pumping; Tables for English Measures; Tables for Metric Measures; Tables for all Measures. There is an index of nine pages.

MUNICIPAL PUBLIC WORKS.

Their Inception, Construction and Management. By S. Whinery. New York, The Macmillan Company, 1903. $1.50 net.

The preface states that this book is intended for the inexperienced city official and for the urban citizen. The veteran in municipal service and the student of municipal administration will not find in the book much that is new to them, although they may find that some matters are presented from points of view different from those to which they have been accustomed. The author has tried to avoid technical treatment of the subjects, and has introduced statistics and details only where they seemed necessary to illustrate or enforce the general statements. The idea has been to deal with principles rather than with details of practice. The Contents are: Importance of Municipal Public Works; Municipal Organization; Preparations for Municipal Work; Direct Work *vs.* Contract Work; Advertising, Opening Bids, and Awarding Contracts; The Contract; The Contractor; The Supervision of Public Work; Maintenance and Repair of Public Work; Economy, Real and False; Guaranteeing Public Work; Special Assessments; Municipal Accounts and Uniform Accounting; Municipal Ownership; Quasi-Public Corporations and their Control.

PRACTICAL FARM DRAINAGE.

Why, When, and How to Tile Drain. By C. G. Elliott. Cloth, 7½ x 5 ins., 7 + 92 pp., illus. New York, John Wiley & Sons, 1903. $1.00.

This book is intended for those who are interested in the subject of farm drainage. It gives to the farmer in a concise and plain manner, the elementary knowledge of why, when, where and how to drain his farm. The practical methods described have been well tested, and are now in constant use by practical men. The chapter headings are: Soils and the Relation of Drainage to Them; Action of Drains Upon the Soil; Leveling and Locating Drains; Depth and Size of Drains; Practical Details of the Work; Ditching Machines; Cost and Profit; Road Drainage.

EARTHWORK AND ITS COST.

By Halbert Powers Gillette, M. Am. Inst. M. E. Cloth, 8 x 5 ins., 10 + 244 pp., illus. New York, The Engineering News Publishing Co., 1903. $2.00.

The author states in the preface that his principal object in this book has been to outline rational methods and rules to be used in cost calculation of earthwork, and that

* Unless otherwise specified, books in this list have been donated by the Publishers.

the only way a truly economic design for a structure can be made is by knowing every item of actual cost, and this in turn can only be known by a study of the tools and methods used in construction. As a class book and as an office book, this volume is intended to be of service in indicating the proper methods of solving problems of engineering economics in general, as well as those of earthwork in particular. The Contents are: Introduction; Earth Shrinkage; Earth Classification; Cost of Loosening and Shoveling; Cost of Dumping, Spreading, Rolling, etc.; Cost by Wheelbarrows and Carts; Cost by Wagons; Cost by Buck and Drag Scrapers; Cost by Wheel Scrapers; Cost by the Elevating Grader; Cost by Steam Shovels; Cost by Cars; How to Handle a Steam Shovel Plant; Summary and Table of Costs; Cost of Trenching and Pipe Laying; The Cost of Hydraulic Excavation; Cost of Dredging; Miscellaneous Cost Data; Frozen Earth; Earth and Earth Structures; Appendix A, Rapid Field and Office Survey Work; Appendix B, Overhaul Calculation; Appendix C, A Small "Home Made" Dipper Dredge or Steam Shovel. There is an index of ten pages.

NOTES ON TRACK

Construction and Maintenance. By W. M. Camp, M. Am. Soc. C. E. Cloth, 10 x 7 ins., 8 + 1 2¼ pp, illus. W. M. Camp, Chicago, 1903. $3.00. (For the foreign trade issued in two volumes at $3.50.)

The author states in the preface that this book treats of the construction and maintenance of railroad track from the standpoints both of the trackman and the engineer, and gives a thorough-going treatment of details, as well as of general principles. The book was published originally as a series of articles in the *Railway and Engineering Review*, but in the revision for its publication in book form, the volume of matter contained in the articles has been greatly increased and elaborated upon. The aim has been to follow practice down to date and give reference to all new improvements which seem likely to assume future importance. Every phase of track construction and track work has been treated, special attention having been paid to costs and other data, and particularly to the development of modern labor-saving machinery in track work. The chapter headings are: Track Foundation; Track Materials; Track-Laying; Ballasting; Curves; Switching Arrangements and Appliances; Track Maintenance; Double-Tracking; Track Tools; Work Trains; Miscellaneous; Organization; Supplementary Notes and Tables. There is an index of eighteen pages.

THE CAR BUILDERS' DICTIONARY.

An Illustrated Vocabulary of Terms which Designate American Railroad Cars, Their Parts, Attachments, and Details of Construction. Compiled for the Master Car Builders' Association, by Rodney Hitt, Assisted by A. M. Waitt, J. S. Lentz, W. P. Appleyard. 1903 Edition. Morocco, 12 x 8½ ins., 374 pp., illus. New York, *The Railroad Gazette*, 1903. $5.00.

The original idea of the Car Builders' Dictionary, as stated in the preface, was to standardize car-building language. Since 1895, however, the book has been used largely as a guide for ordering, designing and specifying cars, and parts of cars, and the present edition has been prepared with a view to facilitate its use for such purposes. While the definitions have not been materially changed in this edition, they have been carefully edited in order to eliminate the ancient history which many of them contained, to condense and modernize the descriptive matter, and to make that part of the book more of a ready-reference section than an encyclopedia. The number of illustrations has been reduced from 5,683 in 1895 to 4,971 in 1903, the object being to show nothing that is experimental or rapidly going out of use, but only such devices and cars as are in general use at this time. Wherever possible the name of the maker of each device has been placed under the engraving, and in many cases, the maker's designation, or number of the part has been preserved. One new feature has been added in the general arrangement of the illustrated pages, that of Car-Shop Machinery, the engravings, however, being limited to a few of the most common forms of woodworking machines and pneumatic tools. Particular attention has been given to the selection of drawings of freight-car bodies. Since 1895, the use of steel cars has rapidly increased, and those illustrated represent the latest types, and may be taken as good examples of present practice. Drawings for wooden cars are given more in detail. The illustrations of the types of the standard systems of framing for passenger cars cover a large proportion of the passenger equipment now in use. The treatment of electric cars has been meager. In preparing that part of the book which includes the Master Car Builders' standards and recommended practice, the aim has been to preserve as nearly as possible the order in which the engravings appear in the *Proceedings* of the Association, and under each engraving is given the reference to the plates shown in the *Proceedings* for 1902. With one or two exceptions all the historical and descriptive matter printed under the head of Rules for Interchange of Traffic, and Standards and Recommended Practice, has been included in the section of the book devoted to definitions. There is an index of two pages to engravings.

DESIGN OF DYNAMOS.

By Silvanus P. Thompson. Cloth, 9 x 6 ins., 7 + 253 pp., illus. New York, Spon & Chamberlain, 1903. $3.50.

The author states that these notes on Dynamo Design are not intended to supersede the more complete handbooks on the special branch of electrical engineering of which this is only a part, and having been designed primarily for his own students, are purposely confined to continuous-current generators. As the work will be used by engineers, chiefly in Great Britain, in her Colonies, and in the United States, the calculations and data have been expressed in inch measures, but the author has adopted throughout the decimal subdivision of the inch, small lengths being given in mils, and small areas of cross-section in square mils, or, sometimes also, in circular mils, to suit American practice. In the section on Armature Winding Schemes, special attention is given to series-parallel windings, and to the doctrine of the "equivalent ring." The chapter headings are: Dynamo Design as an Art; Magnetic Calculations as Applied to Dynamo Design; Copper Calculations: Coil Windings; Insulating Materials, and their Properties; Armature Winding Schemes; Estimation of Losses, Heating and Pressure Drop; The Design of Continuous-Current Dynamos; Examples of Dynamo Design; Appendix I, Wire-Gauge Tables (Copper), British; II, Wire-Gauge Tables (Copper), American; III, Schedules for Design of Continuous-Current Dynamos. There is an index of thirteen pages.

A MANUAL OF USEFUL INFORMATION AND TABLES APPERTAINING TO THE USE OF STEEL.

As Manufactured by the Passaic Steel Company, Paterson, N. J. For Engineers, Architects and Builders. By Geo. H. Blakeley, M. Am. Soc. C. E. Leather, 7 x 4 ins., 324 pp., illus. New York, 1903. $2.00. (Donated by the Author.)

The present edition remains the same as the 1899 and 1901 editions, with a few minor changes. It is intended to supply special information and tables of value and service to those engaged in the design of structural steel work. Only such matter is given as the author has found to be of service in his own practice. The Contents are: Shapes Manufactured by Passaic Steel Company; Structural Details; Properties of Passaic Structural Shapes; Traverse Strength of Passaic Structural Shapes; Beam Girders; Strength and Deflection of Beams; Moments of Inertia of Usual Sections; Fireproof Construction; Building Laws; Spacing of I-Beams for Floors; Riveted Girders; Suddenly Applied Loads; Lintels; Columns; Properties and Safe Loads; Foundations; Wind Bracing. Wooden Beams; Wooden Columns; Roofs; Bridge Trusses; Passaic Standard Railroad Turntables; Specifications for Structural Steel; Corrugated Iron; Rivets and Pins; Bolts and Nuts; Buckle Plates; Sleeve Nuts; Loop Rods; Eye Bars and Pins; Clevises; Linear Expansion by Heat; Areas and Weights of Bars, Flats and Plates; Miscellaneous Tables; Ultimate Strengths of Materials; Weights of Various Substances; Mensuration; Areas and Circumferences of Circles; Weights and Measures. There is an index of seven pages.

HENDRICKS' COMMERCIAL REGISTER

Of the United States. For Buyers and Sellers. Especially Devoted to the Interests of the Architectural, Mechanical, Engineering, Contracting, Electrical, Railroad, Iron, Steel, Mining, Mill, Quarrying and Kindred Industries. Twelfth Annual Edition. Cloth, 10 x 7½ ins., 46 + 1128 pp. New York, Samuel E. Hendricks Co., 1902. $6.00.

This book is an annual index of the above-mentioned industries, containing names, addresses and business classifications, with full lists of the manufacturers of, and dealers in, everything used in the manufacture of material, machinery and apparatus for these industries. There is an index of forty-six pages.

TRAITÉ DE LA CONDENSATION.

Condensations indépendantes; Condensations centrales; Refroidissement artificiel de l'eau. A l'usage des Constructeurs de machines à vapeur, des Ingénieurs d'usines métallurgiques, de mines, de fabriques de sucre, de produits chimiques, etc. . . et des Elèves des Ecoles Industrielles. Par F. J. Weiss. Traduit par E. Hannebicque. Sur la première édition allemande revue et augmentée par l'auteur. Paper, 10 x 6½ ins., 10 + 507 pp., illus. Paris, Vve. Ch. Dunod, 1903. 20 francs.

This work, notwithstanding its title, deals not only with condensation in the strict sense of the word, but also with all questions connected with condensation. The Con-

tents are: Condensation par Mélange; Condensation par Surface; Temps nécessaire pour établier le vide dans le Condenseur; Puissance nécessaire; Utilité de la Condensation; Calcul complet d'une grande Condensation centrale; Conduite d'échappement; Régulation des machines à Condensation; Distribution Weiss; De la Condensation dans les Machines; Refroidissement artificiel de l'eau; Tables de Regnault.

GEMEINFASSLICHE DARSTELLUNG DES EISENHÜTTENWESENS.

Herausgegeben vom Verein Deutscher Eisenhüttenleute in Düsseldorf. 5. Auflage. Cloth, 9 x 6 ins., 12 + 164 pp., illus. A. Bagel, Düsseldorf, 1903. 3 marks.

The first part of the fifth edition remains almost entirely unchanged, whereas the second part has received many additions which correspond to the changes in the economical situation of the iron industry. The appendix has also been enlarged by lists of German beam, rail, bar, hoop, rough tin, refined tin, wire, and pipe rolling mills, as well as the German cast-iron pipe works. The chapter headings are: Die Darstellung des Eisens; Die Darstellung des Roheisens; Die Darstellung des schmiedbaren Eisens; Die Formgebungsarbeiten; Wirtschaftliche Bedeutung des Eisengewerbes; Anhang.

Gifts have also been received from the following:

Ala.—R. R. Comm. 1 vol.
Allen, W. F. 1 bound vol.
Am. Ceramic Soc. 1 vol.
Am. Electrochemical Soc. 1 bound vol.
Am. Inst. Elec. Engrs. 1 bound vol.
Am. Iron & Steel Assoc. 1 pam.
Am. Street Ry. Assoc. 2 vol.
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ERLANDSEN, OSCAR.....Asst. Engr., Dept. of Bridges, 32 Sutton Pl., New York City.

FOX, STEPHENSON WATERS.....Cons. Engr., Room 403, Kansas City Life Bldg., Kansas City, Mo.

GRESHAM, ROBERT HALL.....Engr. for Pan Handle & Gulf Ry., San Antonio, Tex.

GRANT, EMERSON WARREN.....Eng. Dept, A., T. & S. F. Ry., Rural Route No. 6, Topeka, Kans.

HALL, JULIEN ASTIN.....Cons. Engr., Wenonda, Va.

HARRIS, ELMO GOLIGHTLY.....49 Owen Ave., Lansdowne, Pa.

HARTS, WILLIAM WRIGHT.....Capt., Corps of Engrs., U. S. A., Custom House, Portland, Ore.

HEDRICK, IRA GRANT.....(Waddell & Hedrick, Cons. Engrs.), 608 New Nelson Bldg., Kansas City, Mo.

HERRICK, HENRY AUGUSTUS.....Hydr. and Mill Engr., 162 Summer St., Waltham, Mass.

HOLT, HERBERT SAMUEL.....Care, Montreal Light, Heat & Power Co., Montreal, Que., Canada.

HOTCHKISS, CHARLES WILCOX.....Pres., Indiana Harbor R. R. Co., 401 La Salle Station, Chicago, Ill.

HOUGH, ULYSSES B.....Care, Edison Elec. Co., Edison, Cal.

HOWARD, FREDERICK BILLINGS.....Grosse Ile, Wayne Co., Mich.

HYDE, ABRAHAM LINCOLN.....Asst. Prof. of Civ. Eng., Univ. of Missouri, Columbia, Mo.

KEITH, HERBERT CARY.....Chf. Engr, MacArthur Bros. Co., 11 Pine St., New York City.

LANGTON, JOHN.....99 John St., New York City.

LINVILLE, JACOB HAYS.....4605 Springfield Ave., Philadelphia, Pa.

MCKEOWN, THOMAS.....19 Winspear Ave., Buffalo, N. Y.

MCVEAN, JOHN JAY.....100 Jefferson Ave., Grand Rapids, Mich.

MOLITOR, FREDERIC ALBERT.....Chf. Engr., Midland Val. R. R. Co., The Cherokee Constr. Co.; Pres. and Chf. Engr., Cent. R. R. Co. of Ark., Fort Smith, Ark.

MORSE, CHARLES ADELBERT.....Acting Chf. Engr., A., T. & S. F. Ry., 827 Harrison St., Topeka, Kans.

MOSMAN, ALONZO TYLER.....Asst., U. S. Coast and Geodetic Survey, 189 Montague St., Brooklyn, N. Y.

MOSSCROP, ALFRED MITTON.....Vice-Pres. and Mgr., Baltimore Bridge Co., Care, Dorman, Long & Co., Middlesbrough, England.

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NICHOLS, EDWIN JAY.....Res. Engr., St. L. S. W. Ry. Co., Clear Lake, Iowa.
PAINE, ARTHUR BICKLEY.....Room 228, Bourse Bldg., Philadelphia, Pa.
PERKINS, EDMUND TAYLOR.....Engr., Reclamation Service, U. S. Geological Survey, 534 Byrne Bldg., Los Angeles, Cal.
PEW, ARTHUR.....Hawkinsville, Ga.
PHILLIPS, JOSEPH LESLIE.....Director of Compañia de Inguarán, Apartado postal No. 752, City of Mexico, Mexico.
PURDY, CORYDON TYLER.....78 Fifth Ave., New York City.
RAYMOND, CHARLES WALKER.....Lt.-Col., Corps of Engrs., Room E 8, Army Bldg., 39 Whitehall St., New York City.
REED, MELVILLE EMERSON.....Hastings, Minn.
RIPLEY, HENRY CLAY.....Contr., Rockport, Tex.
ROBINSON, ARTHUR WELLS.....14 Phillips Sq., Montreal, Que., Canada.
ROGERS, MERRITT HARRISON.....Cons. Engr., 1314 Gilpin St., Denver, Colo.
ROOD, HENRY MARTYN.....163 William St., Port Chester, N. Y.
ROWE, SAMUEL MCMATH.....Room 364, Monadnock, Chicago, Ill.
RUST, HENRY BEDINGER.....Supt., The Rust Boiler Co., 917 Frick Bldg., Pittsburg, Pa.
SABIN, ALPHEUS TIMOTHY.....810 Fisher Bldg., Chicago, Ill.
SABIN, LOUIS CARLTON.....Asst. Engr., Engr. Dept., U. S. A., Sault Ste. Marie, Mich.
SACKETT, JOHN WARREN.....U. S. Engr. Office, Jacksonville, Fla.
SEYMOUR, HORATIO.....The Olbiston, 371 Genesee St., Utica, N. Y.
SIMS, ALFRED VARLEY.....Prof. of Civ. Eng., Univ. of Iowa, Wenonda, Pittsylvania Co., Va.
STANFORD, HOMER REED.....Civ. Engr., U. S. N., U. S. Navy Yard, Pensacola, Fla.
STEPHENS, CLINTON F.....Security Bldg., St. Louis, Mo.
STEVENS, HORACE EDWARD.....530 Grand Ave., St. Paul, Minn.
STOREY, WILLIAM BENSON, Jr.....641 Market St., San Francisco, Cal.
STUART, ALFRED ALLEN.....15 Des Grisons St., Quebec, Que., Canada.
STUART, FRANCIS LEE.....Dist. Engr., B. & O. R. R., 6 Park St., Cumberland, Md.
SYMONS, THOMAS WILLIAM.....Col., Corps of Engrs., U. S. A., Office of Public Bldgs. and Grounds, Lemon Bldg., Washington, D. C.
TOWLE, STEVENSON.....Civ. and Cons. Engr., 7 East 42d St., New York City.
TUCKER, LESTER WALDO.....Room 515, Winthrop Bldg., Boston, Mass.

TURNER, NATHANIEL.....53 B. Calle de Ocampo, Monterey, N. L., Mexico.
VANDEVANTER, CHARLES OSCAR.....(Vandevanter & Hood), 920 Equitable Bldg., Baltimore, Md.
WARNER, EDWIN HALL.....Care, Columbia Impvt. Co., Tacoma, Wash.
WILLARD, JAMES EAGER.....Grenada, Miss.
WILSON, GEORGE LEVERETT.....Engr. and Roadmaster, Twin City Rap. Trans. Co., Minneapolis, Minn.

ASSOCIATE MEMBERS.

ALLAN, ALEXANDER GEORGE.....Res. Engr., A., T. & S. F. Ry., 426 Elmwood Ave., Topeka, Kans.
ARCHER, STEVENSON, Jr.....Res. Engr., Mo. Pac. Ry., Natchez, Miss.
BARNEY, PERCY CANFIELD.....Dept. of Yards and Docks, Navy Yard, New York City.
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BOYD, JAMES CHURCHILL.....Crocketts Springs, Montgomery Co., Va.
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BROWNE, JAMES SIMPSON.....Div. Engr., N. Y., N. H. & H. R. R., 309 Union Station, Providence, R. I.
COX, LEONARD MARTIN.....Civ. Engr., U. S. N., Care, Maryland Steel Co., Sparrows Point, Md.
DERLETH, CHARLES, Jr.....Univ. of California, Berkeley, Cal.
DE VOU, JAMES LAIRD.....Care, Am. Bridge Co., Erecting Dept., 51st and Butler Sts., Pittsburg, Pa.
FERGUSON, WILLIAM HASTINGS.....Supt. of Constr., Illinois Steel Co., 5845 Madison Ave., Chicago, Ill.
FOX, WALTER GORDON.....11 Broadway, Room 1168, New York City.
FRICK, WALTER.....Lewisburg, Union Co., Pa.
GIDEON, ABRAHAM.....Bulls Bridge, Conn.
HARDY, HARRY.....6 Sunderland Terrace, Bayswater, London, W., England.
HASTINGS, FRANK ARNOLD.....Eng. Dept., Am. Bridge Co., 51st and Butler Sts. (Res., 67 South Dithridge St., E. E.), Pittsburg, Pa.

HILLIARD, FOSTER HAVEN.....Asst. Engr., Louisiana Purchase Exposition Co., Care, Eng. Dept., World's Fair, St. Louis, Mo.
HUMPHREY, HENRY CYPRIAN.....Provincial Superv., Lucena, Tayabas Province, Philippine Islands.
JANVRIN, NED HERBERT.....824 Third St., Louisville, Ky.
KEAYS, REGINALD HORTON. .....Hotel Illinois, Cairo, Ill.
KYLE, GEORGE ALLAN.....Div. Engr., Grand Trunk Pacific Ry., Winnipeg, Man., Canada.
LAVIS, FRED.....Div. Engr., C., R. I. & P. R. R. Brighton, Iowa.
LEPPER, FRED WILLIAM.....U. S. Supt. of Constr., P. O. Bldg., Memphis, Tenn.
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MYERS, EDWARD WARREN.....U. S. Geological Survey, Malta, Mont.
NELSON, WILLIAM.....Junior Mem., H. Bickford & Co., Lakeport, N. H.
NOBLE, FREDERICK CHARLES.....501 West 120th St., New York City.
OSBOURN, HENRY VAN BUREN.....356 Center St., Redlands, Cal.
PITTS, THOMAS DORSEY.....90 Halsey St., Brooklyn, N. Y.
POTTER, ALEXANDER.....Cons. Engr., 143 Liberty St., New York City.
ROCKWELL, JAMES VINCENT.....Asst. Civ. Engr.. U. S. Navy, Navy Yard, Boston, Mass.
ROSEWATER, WILLIAM MARCUS.....Care, Heyl & Patterson, 51 Water St., Pittsburg, Pa.
SHNEIDER, ANTON.....Summit Hill, Carbon Co., Pa
SESSER, JOHN CORNELIOUS.....131 Pleasant St., Benton Habor, Mich.
SCHOEMAKER, MARSHALL NEY.....Vice-Pres., Am. Concrete-Steel Co., 333 Prudential Bldg., Newark, N. J.
SHORT, WILLIAM AMBROSE DUDLEY.....200 Market St., Lexington. Ky
SPIELMAN, JOHN GODFREY.....50 Wabansia Ave., Chicago, Ill.
STOCKETT, ALFRED WALTON.....P. O. Box 6051, Johannesburg, Transvaal, South Africa.
STRATTON, GEORGE EBER.....Care, U. S. Geological Survey, Engle, N. Mex.
STREHLOW, OSCAR EMIL.....U. S. Engr. Office, Demopolis, Ala.
SWEITZER, NELSON BOWMAN.....Care, U. S. Surveyor General, Portland, Ore.
THOMES, EDWIN HOWARD.....Asst. Engr., 1st Div., Rapid Transit Comm., 13 Astor Pl., New York City (Res., 150 Willett St., Jamaica, N. Y.)
THOMSON, ERNEST BURSLEM.....U. S. Engrs., Jacksonville, Fla.
TOWLE, CHARLES STEWART.....7 East 42d St., New York City.

TYRRELL, WARREN AYRES.....620 Chestnut St., Room 1, St. Louis, Mo.
WILLIAMS, CHARLES PAGE.....Ft. Michie, N. Y., via New London, Conn.
WILLS, ARTHUR JOHN.....3852 Poplar St., Philadelphia, Pa.

ASSOCIATES.

QUIRK, EUGENE MCGRATH.....Mgr., Montreal Quarry Co., 698 Boulevard, Ville St. Louis, Montreal, Que., Canada.
TURRILL, SHERMAN MARSH.....259 West 22d St., New York City.

JUNIORS.

ALLEN, WALTER HINDS.....Civ. Engr., U. S. N., Navy Yard, Brooklyn, N. Y.
BELCHER, WALLACE EDWARD.....Care, Milliken Bros., 11 Broadway, New York City.
BELZNER, THEODORE.....Insp., Rapid Transit R. R. Comm., Sec. 15, 4th Div., 218th St. and Kingsbridge Rd. (Res., 584 Lenox Ave.), New York City.
BISSELL, CLINTON TALCOTT.....313 Lafayette Ave., Brooklyn, N. Y.
BROWN, WILLIAM CLINTON .....512 William St., Montreal, Que., Canada.
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FALK, MYRON SAMUEL.....Tutor, Dept., Civ. Eng., Columbia Univ. (Res., 44 West 53d St.), New York City.
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PROCTOR, RALPH FENNO.....Care, Williams & Whitman, 702 Flatiron Bldg., New York City.

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TAYLOR, HOWARD FLANDERS .....Res. Engr., Gasconade R. R. Constr. Co., Elden, Mo.
THOMPSON, WILFORD ASHFORD.....Engr., Buehler-Cooney Constr. Co., 4636*a* Page Blk., St. Louis, Mo.
THOMSON, ALEXANDER, Jr.....Asst. Engr., Rapid Transit R. R. Comm., 4 Court Sq. (Res., 351*a* Quincy St.), Brooklyn, N. Y.
VAN PELT, SUTTON .....Care, U. S. Engr. Office, Mobile, Ala.
WALKER, EDWARD LLOYD..... ....City Hall, Meadville, Pa.
WHITSON, ABRAHAM UNDERHILL.....Glen Cove, N. Y.
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DEATHS.

BOND, FREDERICK WINN.....Elected Member, December 7th, 1898; died July 12th, 1903.
DUNHAM, CHARLES FREDERICK.....Elected Member, April 2d, 1902; died June 13th, 1903.
FTELEY, ALPHONSE.....Elected Member, January 5th, 1876; died June 11th, 1903.
HARDY, GEORGE RICHARDSON.....Elected Member, November 7th, 1888; died April 2d, 1903.
JONES, BENJAMIN FRANKLIN.....Elected Fellow, June 13th, 1870; died May 19th, 1903.
LIBBY, EDMUND DORMAN.....Elected Member, May 6th, 1885; died April 24th, 1903.
MARTIN, CHARLES CYRIL..... .....Elected Member July 10th, 1872; died July 11th, 1903.
MORISON, GEORGE SHATTUCK .....Elected Member, January 6th, 1875; died July 1st, 1903.
MORSE, HENRY GRANT. .....Elected Member, April 7th, 1880; died June 2d, 1903.
THOMPSON, WILLIAM GEORGE MCNEILL..Elected Member, July 2d, 1879; died May 12th, 1903.
VANDERPOOL, EUGENE.....Elected Member, September 2d, 1874; died July 12th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(May 12th to Aug. 8th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

The Rupnarayan Bridge, Bengal-Nagpur Railway. Stephen Martin-Leake, Assoc. M Inst. C. E. (63) Vol. cli.
Victoria Bridge over the Brisbane River, Brisbane, Queensland. Alfred Barton Brady, M. Inst. C. E. (63) Vol. cli.
Bridge Building and Bridge Works in the United States.* (12) Serial beginning Jan. 16.
Curves of Maximum Bending Moment.* Arthur L. Bell. (12) May 8.
The King Edward VII. Bridge at Kew.* (11) Serial beginning May 15.
The Polar Moment of Inertia, and Its Graphical Application to Riveted Joints.* C. F. Blake and R. W. Runge. (13) May 21.
Steel Underflooring and Wood Block Pavement for the Roadways of the Williamsburg Bridge.* (13) May 21.
Rail-Concrete Masonry on the New York, Ontario & Western.* (15) May 22.
Standard Plans for Bridges on the Atchison, Topeka & Santa Fé Ry.* (13) May 28.
New Vauxhall Bridge.* (12) Serial beginning May 29.
An Exhibit of Some Curious Lattice Trusses.* Geo. N. Linday. (4) June.
The Stresses on Skew Arches.* W. C. Kernot, M. Am. Soc. C. E. (Paper read before the Victorian Inst. of Engrs.) (13) June 11.
Reinforced Concrete Bridge over River Des Peres, Forest Park, St. Louis, Mo.* (13) June 11.
Bridges on the Eastern Illinois & St. Louis.* (15) June 12.
The Springville Bridge.* (14) June 13.
The Raritan River Stone Arch Bridge of the Pennsylvania R. R., at New Brunswick, N. J.* (13) June 18.
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Concrete Arch Bridge over the San Juan River on the Road from Santiago de Cuba to Caney.* Eduardo J. Chibas, M. Am. Soc. C. E. (13) June 18.
The Merits of Grillage on a Pile Foundation.* J. C. Hain. Paper read before Iowa Ry. Club.) (15) June 19.
Comparison of Eye-Bar Chains with Steel-Wire Cables for the Manhattan Bridge. (13) June 25; (14) June 27.
Wire Cables *versus* Eye-bar Chains for Suspension Bridges. Wilhelm Hildenbrand, M. Am. Soc. C. E. (14) July 4.
The Proposed Brooklyn Bridge Terminal and New York Municipal Building.* (13) July 9.
Scherzer Rolling-lift Plate Girder Railroad Bridges.* (14) July 11.
Pyrmont Bridge, Sydney, Australia.* John Plummer. (19) July 11.
Replacing a Suspension Bridge by a Masonry Arch.* (13) July 16.
A Concrete-Steel Three-Hinged Arch Bridge.* (13) July 16.
The Widening of London Bridge.* Harold J. Shepstone. (19) Aug. 1.
The Plattsmouth Bridge of the Burlington.* (15) Aug. 7.
Erection of Manhattan Valley Viaduct.* (14) Aug. 8; (20) July 30.
The Great Miami River Highway Bridge, Dayton, Ohio.* (14) Aug. 8.
Le Pont de Gignac sur l'Hérault, 1774–1810: Notice Descriptive et Historique. F. De Dartien. (43) 4e Trimestre, 1902.
Pont Suspendu Semi-Rigide de Vernaison (Rhone).* Ch. Dantin. (33) July 4.

Electrical.

High-Speed Electrical Generating Plant. Thomas Herbert Minshall. (63) Vol. cli.
The Operation of Automatic Circuit-Breakers, and the Effects of Short Circuits on Dynamos. Bertram Hopkinson. (63) Vol. cli.
A System of Electric Lighting for Cars. James F. McElroy. (42) Apr.
Burning of Wooden Pins on High Tension Transmission Lines. C. C. Chesney. (42) Apr.
Transposition and Relative Location of Power and Telephone Wires. P. M. Lincoln. (42) Apr.
The Testing of Insulators. F. O. Blackwell. (42) Apr.
Mechanical Specifications of a Proposed Standard Insulator Pin. Ralph D. Mershon. (42) Apr.
Methods of Speed Control. William Cooper. (42) Apr.
Economical and Safe Limits in the Size of Central Stations. H. A. Lardner. (42) May.
Safety Devices in Central Stations and Substations. Philip Torchio. (42) May.
Multiple *versus* Independent Operation of Units and Central Stations. Peter Junkersfeld. (42) May.
The Manufacture of Incandescent Lamps.* (11) May 8.
Divided Multiple Switchboards: An Efficient Telephone System for the World's Capitals.* W. Aitken. (Abstract of paper read before the Inst. of Elec. Engrs.) (26) Serial beginning May 15.
The Crompton Potentiometer for Electrical Measurements with Direct Current Supply. (19) May 16.
Long-Distance High-Tension Transmission of Power in California.* Hamilton Wright. (46) May 16.
The New Electricity Works at Worcester.* (26) May 22.
Recent Development of the Chicago Edison and Commonwealth Electric Systems.* (27) May 23.

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* Illustrated.

Electrical—(Continued).

Development of Light and Power Business at Red Oak, Iowa.* (27) May 23.
The Pontiac Light and Water Co., Pontiac, Ill.* (27) May 23.
An Automatic Electric Lift.* (47) May 23.
Tests of Electric Driving Equipment in the Works of the Morden Frog & Crossing Co. Miles F. Moore. (13) May 28.
Estimates for an Electric Plant for Public Lighting in New York City. (13) May 28.
Electric Lighting of Aldershot Camp.* (26) May 29.
Electric Power and Lighting in the New Government Building at San Francisco.* (14) May 30.
Applications of Electricity in Vickers, Sons and Maxim's Works. A. D. Williamson. (Paper read before the Inst. of Elec. Engrs.) (22) Serial beginning May 15; (47) Serial beginning May 30.
The 25 000 Volt Transmission Plant of the South Bend Electric Company.* (27) May 30.
Great Electric Installations of Italy: The Hydro-Electric Station of Cenischa.* Enrico Bignami. (9) June.
The Electric Furnace.* (10) June.
The Progress in Wireless Telegraphy. William Maver, Jr. (10) June.
Electric Driving in Workshops. A. D. Williamson. (Paper read before the Inst. of Elec. Engrs.) (11) Serial beginning June 5; abstract (47) June 6.
Stassano Electric Furnace Steel Process.* (26) June 5.
The Insulation and Mechanical Protection of Electric Wiring. (26) June 5.
The Power Plant of the Neversink Light and Power Company.* (14) June 6.
Construction and Operation of a Freight Car Driven by Induction Motors.* A. B. Weeks. (17) June 6.
Railway and Lighting Storage Battery at Milwaukee.* (17) June 6; (27) June 13.
Modern English Power Plant.* (17) June 6.
Relative Advantages of Electrical and Mechanical Methods of Variable Speed Control for General Power Service. William Cooper. (Read before the National Elec. Light Assoc.) (18) June 6.
Ashtabula Telephone Exchange.* (27) June 6.
Commutator Losses. W. B. Hird. (Paper read before Glasgow Section, Inst. Elec. Engrs.) (47) June 6.
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The Development of the Current Interrupter. J. Wright. (26) Serial beginning June 12.
Rebuilding the Duluth General Electric Company's Station.* Clifford L. Higgins. (27) June 13.
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The Cost of High Tension Lines. (17) June 20.
New Central Station of the Commonwealth Electric Company of Chicago.* (20) June 18.
High Tension Transformers. J. W. Farley. (Paper read before Canadian Electrical Assoc.) (62) June 18.
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Collins Wireless Telephone System.* T. Byard Collins. (27) June 20.
A Contribution to the Subject of Aging of Sheet Steel. Thomas S. Allen. (27) June 20.
The Gruhn Telechirograph for Transmission of Handwriting.* (27) June 20.
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The Development of Electric Station Power Plant. Elihu Thomson. (Paper read before National Elec. Light Assoc.) (20) June 25; abstract (13) June 4.
Electricity in the Shop. H. M. Phillips. (62) Serial beginning June 25.
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Westinghouse Type F Induction Motor.* (40) June 26; (18) July 25.
A Note on Three-Phase Power Measurement. F. A. Fish. (27) June 27.
Electric Power from the Hudson.* Alton D. Adams. (27) June 27.
German Tests of the Pupin System of Long Distance Telephony.* (46) June 27.
Applications of Electricity to Agriculture.* Émile Guarini. (9) July.
Electrical Operation in Central Stations.* Howard W. Leitch. (64) July.
High-Pressure Steam Heating Transmission and Electric Lighting Plant at Dresden.* Franz Köster. (14) July 4.
Improvements at the Stephenson Works.* (17) July 4.
The Special Telephone System of the Manhattan Elevated Railway, New York City.* (27) July 4.
An Automatic Telephone Exchange for Chicago.* R. E. Sack. (27) July 4.
Composite System of Electrical Transmission and Distribution. Frederick Bedell. (Paper read before the Cleveland Electric Club.) (27) July 4; (24) July 13.
The Telechirograph—A New Facsimile Telegraph.* (46) July 4.
The Rand Central Electric Works.* (26) July 10.
Private Telephone System of the Manhattan Railway Company.* (17) July 11.
Some Recent Effects of Electrolytic Action upon Underground Mains and Other Metals.* A. A. Knudson. (Paper read before the Amer. Water-Works Assoc.) (24) July 13.
The Electric Plant at Tredegar.* (22) July 17.

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Electrical—(Continued).

Continuous and Alternating Currents Applied to Mining. Ellis H. Crapper. (22) July 17.
Compounded Asynchronous Machinery. G. Hooghwinkel, M. I. E. E. (26) Serial beginning July 17.
Utica Home Telephone Company's Exchange.* F. L. Martin. (27) July 18.
Surveys for Electrolysis and Their Results. D. H. Maury, M. Am. Soc. C. E. (Paper read before Amer. Water-Works Assoc.) (13) July 23.
On the Preservation of Instruments and Machinery in Bengal. Paul Bruhl. (Paper read before the Calcutta Section of the Inst. of Elec. Engrs.) (12) Serial beginning July 24.
Hertzian Wave Telegraphy.* J. A. Fleming. (29) Serial beginning July 24.
The Batault Electric Wattmeter for Simple Alternating and Polyphase Currents.* (19) July 25.
Electrostatic High-Pressure Voltmeter.* (47) July 25.
Defective Machine Insulation. C. E. Farrington. (3) Aug.
Care and Management of Electric Generators.* Edwin W. Creed. (64) Aug.
Electric Motors in an Iron Works.* (14) Aug. 1.
The Missouri River Power Station of the Metropolitan Street Railway Company, of Kansas City, Mo.* (17) Aug. 1.
An Electrically-Operated Coal Hoist.* Richard Lamb. (27) Aug. 1.
The Schuckert Electric Works at Nuremberg, Germany.* S. N. Taylor. (27) Aug. 1.
The Lodge-Muirhead System of Wireless Telegraphy.* A. Frederick Collins. (27) Aug. 1.
The Power Plant for the Metropolitan Street Railway of Paris.* Emile Guarini. (19) Aug. 8.
Effect of Series Resistance in the Primary Circuit of a Transformer.* H. A. Pikler. (27) Aug. 8.
Hydraulic-Electric Development of the Neversink Light and Power Company, Middletown, N. Y.* (27) Aug. 8.
Eccentricities of the Static Discharge.* Walton Harrison. (46) Aug. 8.
Applications de l'Électricité à la Distribution de la Force Motrice dans les Ateliers et les Diverses Exploitations Industrielles.* E. De Marchena. (32) May.
Applications du Rappel Bréguet-Rodary aux Communications Télégraphiques et Téléphoniques sur les Chemins de Fer de P.-L.-M.* Rodary. (38) June.
Usine Hydro-Électrique de Cauvery Falls (Inde).* F. Drouin. (33) July 25.

Marine.

Marine Installations for the Carriage of Refrigerated Cargoes.* R. Balfour. (Paper read before the Inst. of Naval Archts.) (11) May 8.
H. M. S. *Commonwealth.** (12) May 22.
A Comparison of the German Battleship *Wettin* with the *Maine.** Fred. T. Jane. (46) June 13.
Performance of Babcock & Wilcox Boilers in a Gunboat. Henry C. Dinger. (Reprinted from the *Journal* of the Amer. Soc. of Naval Engrs.) (47) June 20.
The 120-Ton Floating Derrick for the Norfolk Navy Yard.* (13) June 25.
Coaling Warships at Sea.* Herbert C. Fyfe. (46) June 27.
The Auxiliary Machinery of Steam Vessels.* Jasper E. Cooper. (10) Serial beginning July.
The *Kaiser Wilhelm II:* The Newest and Largest Atlantic Liner.* Gustav H. Schwab. (10) July.
On Mercantile Cruisers Fitted with Housing Propellers.* James Hamilton. (Paper read before the Inst. of Naval Archts.) (11) July 8.
Channel Steamship *The Queen.* (12) July 8.
T.—S. S. *Kaiser Wilhelm II.** (11) July 10.
Cross-Channel Steamers. J. H. Biles. (Paper read before the Inst. of Naval Archts.) (11) July 10.
The Steam Turbine and Its Application to the Propulsion of Vessels.* C. A. Parsons. (Paper read before the Inst. of Naval Archts.) (11) Serial beginning July 10.
A 6 000-Ton Floating Depositing Pontoon Dock.* (46) July 11.
Fast Coaling Ships for Our Navy.* E. H. Tennyson D'Eyncourt. (Paper read before the Inst. of Naval Archts.) (11) July 17.
The Clyde and Naval Work. (12) Serial beginning July 17.
The New Graving Dock of the Kawasaki Dockyard Company, Kobe.* (11) July 24.
The Griffin Marine Type Hydro-Oil Engines.* (11) July 24.
The New York Shipbuilding Company's Plant, Camden, N. J.; Pt. II.* (14) July 25.
Development in Floating Dry-Docks.* Joseph J. Shultz. (9) Aug.
Modern American Launch Motors.* W. P. Stephens. (10) Aug.
De l'Emploi des Moteurs à Pétrole à Bord des Bateaux de Pêche.* J. Pérard. (32). Mar.

Mechanical.

Mechanical Stokers.* Edwin Fitts. (58) Apr.
Commercial Gases for Power Purposes. Alexander M. Gow. (58) May.
Power and Economy of the Gas Engine as Influenced by the Fuel. Wm. P. Flint. (58) May.

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Mechanical—(Continued).

Coal-Handling Machinery and Its Application to Steam Power Plants.* T. F. Webster (58) May.
Utilizing Water Gas in the Production of Illuminating and Heating Gases. William Young. (66) May 5.
The Construction and Working of Machine Reamers and Reaming Heads.* (11) Serial beginning May 8.
The Wilskemp Smoke Consumer.* (12) May 8.
Dunlop's Reversible Self-Starting Internal Combustion Engines.* (47) May 9.
Retort Stoking by Electricity.* (66) May 12.
A Small "Home-Made" Dipper Dredge or Steam Shovel.* (13) May 14.
A New Pneumatic Hammer.* (13) May 14.
Power Plant of the Government Printing Office at Washington.* (14) Serial beginning May 16.
A Cold Storage Warehouse.* (14) May 16.
The Serpollet Steam Automobile.* (19) Serial beginning May 16.
Water in Steam. James Andrew. (Paper read before the Glasgow Technical College Soc.) (47) Serial beginning May 16.
The Choice of a Steam Boiler. C. E. Stromeyer. (Paper read before the Civil and Mech. Engrs. Soc.) (47) May 16.
The Dellwik-Fleischer Process of Carburetting Water Gas by Passing It Into Retorts. M. Leconte. (Abstract of paper read before the Société Technique du Gaz en France.) (66) Serial beginning May 19.
Two Experiments in Smoke Preventing Furnaces.* (13) May 21.
Gas-Driven Blowing Engine (Delamere-Debouteville & Cockerill System).* (11) May 22.
Blast Furnace Gas Engines and Steam Engines. (11) May 22.
Milling Machine Methods.* (12) May 22.
The Curtis Steam Turbine.* (27) May 23; (14) July 11.
The New Parisian Retort Charging-Machine and Discharging-Ram.* (66) May 26.
The Present and Future of the Hastings Gas-Works.* (60) May 26.
Reducing Breakage in Coal Shipping.* (13) May 28.
Some Present Requirements in Laundry Machinery.* Henry Waring. (11) May 29.
Continental Engine Construction. (12) Serial beginning May 29.
The Expansion, Separation and Compression of Wet Steam. Robert H. Smith. (12) May 29.
Friction in Gas Engines. H. E. Thompson. (Paper reprinted from the *Proceedings* of the Soc. of Mech. Engrs. of Cornell Univ.) (47) May 30.
Sulphur-Dioxide and the Binary Engine. R. H. Thurston. (3) June.
Practical Liquid Air Possibilities for Refrigeration and Power.* Carl von Linde. (10) June.
The Equipment of Machine Shops.* Joseph Horner. (10) June.
Lignite Burning in Locomotives, Burlington & Missouri River Railroad: Analysis of Smokebox Gases. M. H. Wickhorst. (25) June.
Group Driving of Machine Tools. J. C. Steen. (25) June.
Motor Driven Machine Tools: Examples of Individual Drives Applied to Boring Mills.* (25) June.
Comparative Tests of California Crude Oils; Atchison, Topeka & Santa Fé Railway. (25) June.
Power Test of Group Drive Motors: Records of Power Required for the Group Drives at the Roanoke Shops, Norfolk & Western Railway. (25) June.
The Proportions of Modern Locomotives. Lawford H. Fry. (25) June.
Fuel: What We Don't Know About It. Edward Atkinson. (28) June.
Lubricants for Cylinders. R. T. Strohm. (45) June.
The Bellevue Washery of the D., L. & W. R. R. Co., Scranton, Pa.* (45) June.
The Ostergren Oil Engine.* (64) June; (14) June 6; (46) June 6; (62) June 25.
Tests of Superheated Steam.* M. Schroter. (64) June.
The Condensing Plant of the New York Rapid Transit Power House.* (64) June.
Report of the Committee Appointed by the Ohio Gas Light Association to Determine Standard Methods of Testing Fuel Gas Appliances.* (24) Serial beginning June 1.
The Heisler Compensating Gear for Direct Acting Pumping Engines.* (13) June 4.
A Circular Storage System for 50 000 Tons of Coal.* (20) June 4.
Springs and Their Use.* Ivar Kirkegaard. (20) June 4.
The Reid Ball Bearings.* (20) June 4.
Exhaust-Steam Turbines. (11) June 5.
Relative Advantages of Electrical and Mechanical Methods of Variable Speed Control for General Power Service. William Cooper. (Read before the National Elec. Light Assoc.) (18) June 6.
A New Apparatus for Determining the Resistance of Road Vehicles to Traction.* (46) June 6.
The Self-Carburetting of Water Gas in Gas-Works. (66) June 9.
Burning Illinois Coal without Smoke. L. P. Breckenridge, M. Am. Soc. M. E. (Paper read before the Commercial Club of Chicago.) (13) June 11.
Tests of the Efficiency of Hoisting Tackle. S. L. Wonson. (13) June 11.
Some Tests of Boiler and Furnace Efficiencies.* A. Bement. (Extract of paper read before National Elec. Light Assoc.) (13) June 11.

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Mechanical—(Continued).

The Inefficiency of the Ordinary Lathe for High Speed Cutting. H. M. Norris. (Paper read before the Cincinnati Metal Trades Assoc.) (20) June 11.
A New Charcoal Cooling Process. Bernhard Zwillinger. (20) June 11.
Comparative Test of Beehive and Retort Coal. E. A. Uehling. (20) June 11.
The Kynoch-Fornard Oil-Engine.* (11) June 12.
Britannia Steel Works, Middlesbrough.* (11) Serial beginning June 12.
The Nuremberg Double-Acting Tandem Gas Engines.* (22) June 12.
The Bauer Coke Oven.* (57) June 12.
The Stress on Bolts in Service. John H. Barr. (Reprinted from Sibley Journal of Engineering.) (47) June 13.
Maximum Economical Yield of Gas per Pound of Coal Carbonized. John Somerville. (24) June 15.
Candles and Calories. Vivian B. Lewes. (Lecture delivered before Inst. of Gas Engrs.) (66) June 16.
Photometry and Testing. Walter Grafton. (Paper read before the Inst. of Gas Engrs.) (66) June 16.
The Lewes Process at Tipton.* Sidney O. Stephenson. (66) June 16.
The "Selas" System of Intensified Gas Lighting by Means of an Admixture of Gas and Air.* F. D. Marshall. (Paper read before the Inst. of Gas Engrs.) (66) June 16.
Later Developments in High-Pressure Lighting.* A. W. Onslow. (Paper read before the Inst. of Gas Engrs.) (66) June 16.
Molding Machines of the "Squeezer" or Hand Press Type.* S. H. Stupakoff. (Abstract of paper read before Amer. Foundrymen's Assoc.) (13) June 18.
Friction and Lubrication. J. Stormouth. (12) June 19.
Applying a Motor Drive to an Old Lathe.* (15) June 18.
Penwylit Haulage.* (58) June 19.
Progress in Machine Tools.* (18) Serial beginning June 20.
Butler's 5 000 H.-P. 3-Cylinder Double-Acting Compound Gas Engine.* (47) June 20.
Naphthaline. W. H. Birchmore. (Address before Western Gas Assoc.) (24) Serial beginning June 22.
High-Pressure Gas Incandescent Lighting.* William Sugg. (Paper read before the Inst. of Gas Engrs.) (66) June 23; (14) June 27.
The 120-Ton Floating Derrick for the Norfolk Navy Yard.* (13) June 25.
The Moore Vertical Water Tube Boiler.* (20) June 25.
The New Semet-Solvay Coke Oven.* (22) June 26.
The New Shops of the American Locomotive Company at Schenectady.* Lindsay Duncan. (14) June 27.
From Siding to Coke-Store at the Bury Gas-Works.* (66) June 30.
Acetylene Stored and Transported in Safety. John S. Seymour. (3) July.
Liquid Fuel for Power Purposes. Arthur L. Williston. (9) Serial beginning July.
The Auxiliary Machinery of Steam Vessels.* Jasper E. Cooper. (10) Serial beginning July.
Milling as a Method of Machining; Its Development in American Shop Practice.* Charles S. Gingrich. (10) July.
High Pressure Steam Piping. William Andrews. (Paper read before the Engine Builders' Assoc.) (64) July.
Graphical Chart for the Solution of Valve Gear Problems. W. F. Durand. (64) July.
Rope Transmission of Power. D. B. Dixon. (62) July 2.
The Automobile Congress at Paris. (12) Serial beginning July 3.
Improvements at the Stephenson Works.* (17) July 4.
Warren Rotary Engine.* (27) July 4; (20) July 9; (14) June 27.
The Capabilities of High-Speed Steel. Wm. Lodge. (Paper read before Amer. Foundrymen's Assoc.) (47) July 4.
Heat Conductivity of Gas Retorts.* H. A. Wheeler. (Paper read before the Western Gas Assoc.) (24) July 6.
Quadrupling the Capacity of an Ordinary Purifier House at Very Small Cost.* F. H. Shelton. (Paper read before the Western Gas Assoc.) (24) July 6.
The Old and the New at Shrewsbury (Gas Works).* (66) July 7.
The Buhlmann System of Burning-Off, Shaping, and Seasoning Mantles.* (66) July 7.
A New Molding Press for Making Cement Pipe.* (13) July 9.
Springs and Spring Steel. William Metcalf. (Paper read before Amer. Soc. for Testing Materials.) (20) July 9; (13) July 30.
The Manufacture of Armour-Plate Bolts.* (11) July 10.
Some New Types of Superheaters.* W. H. Watkinson. (Paper read before the Inst. of Naval Archts.) (11) July 10; (12) July 17; abstract (47) Serial beginning July 11.
A New Theory of Heat Power Plants. Robert H. Smith. (12) Serial beginning July 10.
Automatic Wheel-Cutting Machine.* (12) July 10.
An Improved System of Engine Stops.* (19) July 11.
Radial Drilling Machines.* Thomas R. Shaw. (47) Serial beginning July 11.
Practical Belt Driving. John Tullis. (Abstract of paper read before the Aberdeen Mech. Soc.) (47) July 11.
A Comparison between the First Cost of Inclined and Horizontal Retorts. Frère. (Paper read before the Société Technique du Gaz.) (66) July 14.
The Universal Pipe and Fittings.* (20) July 16.
Condensing Plant for Central Electric Stations. R. D. Summerfield. (11) Serial beginning July 17.

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Mechanical—(Continued).

Cranes on Dover Pier.* (12) July 17.
Steam Autocar Notes.* (12) July 17.
Cylinder Oil and Cylinder Lubrication. Henry M. Wells. (12) Serial beginning July 17.
Air and Gas Mixtures, Explosion Pressures, and Cylinder Proportions of Gas Engines. James Dunlop. (47) July 18.
Sulphate of Ammonia Making by a New Process.* J. Ballantyne. (Paper read before the Inst. of Gas Engrs.) (24) July 20.
Water Gas Manufacture by the Kramers and Aarts Process. (66) July 21.
Portable Pneumatic Revolving Cranes.* (13) July 23.
The Plant of the Hudson Portland Cement Co., at Hudson, N. Y.* (13) July 23.
French Tests of Alcohol Motors. C. C. Longridge, M. I. Mech. E. (12) July 24.
Coal Washing and Screening Plants.* (22) July 24.
The Mechanical Plant of a Columbia, S. C., Office Building.* (14) July 25.
The Operation of the Rateau Steam Turbine. (17) July 25.
The Inefficiency of the Standard Lathe for High-Speed Cutting. H. M. Norris. (Paper read before Amer. Foundrymen's Assoc.) (18) July 25.
The Rateau Steam Turbine.* (27) July 25.
The Management and Working of Boilers.* Horace Boot. (Abstract of paper read before Incorporated Mun. Elec. Assoc.) (47) July 25.
A Machine for Sorting and Washing Pan-Breeze.* (24) July 27.
A German Installation of West's Retort-Stoking Machinery. (66) July 28.
Fuel Oil. John F. Rowland, Jr. (3) Aug.
The Utilization of Blast-Furnace Gases for Power Purposes. Charles Kirchhoff. (3) Aug.
Natural Sources of Energy; the Probable Extensive Development of Solar Power.* Louis Bell. (10) Aug.
Feed-Water Heaters; Examples from Current American Practice.* William Wallace Christie. (10) Aug.
Modern American Launch Motors.* W. P. Stephens. (10) Aug.
Motor-Driven Machine Tools; the Latest Practice in Applying Individual Drives to Shapers.* (25) Aug.
Woodworking Machinery; Important Developments in Individual Driving by Electric Motors.* (25) Aug.
Beehive Coke Ovens.* (45) Aug.
The Reorganization of the Condensing System of the Manhattan Station.* (64) Aug.
Coal and Oil Fuel Compared. George E. Walsh. (64) Aug.
The Westinghouse Vertical Marine Type Engine.* (64) Aug.
Burning Powdered Coal Under Boilers.* (64) Aug.
A Small Ice Plant at Columbia, S. C.* (14) Aug. 1.
Improvements in Steam Shovels.* Waldon Fawcett. (46) Aug. 1.
The Ore-Carrying Wire Ropeway at Vivero, Spain.* (46) Aug. 1.
Loss of Illuminating Power of Mantles while Burning.* Alfred H. White and M. E. Mueller. (Paper read before the Michigan Gas Assoc.) (24) Aug. 3.
A New Trench Digging Machine.* (13) Aug. 6.
Metallic Packings; Principles of Design Essential for Successful Development. Charles Longstreth, Assoc. Am. Soc. Naval Engrs. (Reprinted from the *Journal* of the Amer. Soc. of Naval Engrs.) (13) Aug. 6.
Note sur les Cables Témoins: Sytème F. Arnodin. F. Arnodin. (32) Mar.
Moteur à Gaz et à Récupération des Calories Actuellement Perdues. Jules Garniér. (32) Mar.
Quelques Progrès Récemment Réalisés dans les Machines à Vapeur.* P. Arrachart. (32) Apr.
Contribution à l'Étude du Fonctionnement Mécanique des Machines Alternatives. R. Lelong. (37) Serial beginning May.
Conditions de Résistance des Pistons des Machines à Vapeur. Codron. (37) Serial beginning May.
Le Moteur Alterno-Rotatif Primat.* (36) May 10.
Equilibrage des Machines.* H. Brillié. (33) Serial beginning May 23.
La Turbine à Vapeur.* Raucour. (36) May 25.
Les Forces Motrices dans les Régions sans Eau et sans Charbon et en Particulier aux Colonies.* A. Lombard. (36) May 25.
Les Condensations Centrales à l'Exposition de Düsseldorf.* P. F. Dujardin. (33) May 30.
Transport par Hélices à 200 Mètres de Distance.* (33) May 30.
Méthode de Calcul des Arbres Chargés Animés de Grandes Vitesses de Rotation. Delaporte. (37) June.
L'Utilisation des Gaz de Hauts Fourneaux. S. Marsolan. (36) June 10.
Le Ballon *Lebaudy*.* G. Espitallier. (33) June 13.
Fabrique de Cellulose et de Papier à Rumford Falls (Etats-Unis).* (33) June 13.
Protection contre le Saut de la Navette dans les Métiers à Tisser.* Henri Marny. (33) Serial beginning June 13.
Transmissions de Mouvement par Courroies ou Cables Enrouleur-Débrayeur du Capitaine Leneveu.* Ch. Dantin. (33) June 20.
Les Nouveaux Appareils d'Eclairage au Gaz par Incandescence.* H. Guérin. (33) June 27.

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Mechanical—(Continued).

Les Turbines à Vapeur.* A. Abraham. (36) Serial beginning July 10.
L'Alcool Considéré Comme Combustible. Edmond Brunet. (36) Serial beginning July 10.
L'Acétylène Dissons et Ses Principales Applications.* A. Janet. (33) July 18.
État Actuel de la Théorie de la Surchauffe de la Vapeur. Hermann Bernard. (33) July 25.

Metallurgical.

The Evolution of the Determination of Iron in Ores. Harrison W. Craver. (58) May.
The Open-Hearth Process. Leandro Cubillo. (22) May 8.
The Application of the Electrical Furnace in Metallurgy.* Albert Keller. (22) May 8; abstract (47) June 13.
The Effect of Flue Dust upon the Thermal Efficiency of Hot Blast Stoves. B. H. Thwaite. (Paper read before the Iron and Steel Inst.) (22) May 8.
The Development of the Continuous Open-Hearth Process. Benjamin Talbot. (Paper read before the Iron and Steel Inst.) (22) May 8; (20) May 14; (11) May 15; (68) May 16; (62) June 4; (49) June 27.
A New Blast Furnace Top.* Axel Sahlin. (Paper read before the Iron and Steel Inst.) (22) May 8; (20) May 14; (11) May 29; (47) June 6.
The Works and Operations of the North-Eastern Steel Company, Middlesbrough-on-Tees.* (22) May 15.
Electrolytic Zinc Extraction by the Hoepfner Process.* E. Guenther. (16) May 16.
Strength of White-Iron Castings as Influenced by Heat Treatment. A. E. Outerbridge, Jr. (Paper read before Amer. Soc. for Testing Materials.) (13) May 21.
The Quality of Pig Iron for Foundry Use as Shown by Fracture and Analysis. S. B. Patterson. (Paper read before the New England Foundrymen's Assoc.) (20) May 21.
The Meune Process for Removing Metallic Obstructions.* (20) May 21.
Smelting at Mt. Lyell, Tasmania.* (16) May 30.
The Works of the Lackawanna Steel Company.* (14) Serial beginning May 30.
Influence of Casting Temperature on Properties of Alloys. Percy Longmuir. (Abstract of paper read before the Iron and Steel Inst.) (47) May 31.
Pig-Iron Casting and Conveying Machinery; Its Development in the United States.* E. A. Uehling. (10) June.
The Advantages of Machine-Cast Pig-Iron. Albert Ladd Colby. (10) June.
Stassano Electric Furnace Steel Process.* (26) June 5.
A Proposed Process for Extracting Copper from Low-Grade Ores. G. D. Van Arsdale. (16) June 6.
Treatment of Low Grade Copper Ores. Edward D. Peters. (16) June 6.
Malleable Cast Iron. Richard Moldenke. (Paper read before the Amer. Foundrymen's Assoc.) (20) June 11; (13) June 11; (62) June 25; (22) July 24.
Blast Furnace Conditions Affecting the Chemical Composition of Foundry Iron. W. Walley Davis. (Abstract of paper read before the Amer. Foundrymen's Assoc.) (20) June 11.
A Point in Concentration. M. A. Knapp. (16) June 20.
Cyaniding in Montana. Matt. W. Alderson. (45) July.
A Study of Alloys Suitable for Bearing Purposes.* G. H. Clamer. (3) July.
The Physical Properties of Malleable Castings as Influenced by the Process of Manufacture. Richard Moldenke, M. Am. Soc. M. E. (Paper read before Amer. Soc. for Testing Materials.) (13) July 9; (47) July 4
Springs and Spring Steel. William Metcalf. (Paper read before Amer. Soc. for Testing Materials.) (20) July 9; (13) July 30.
On Adobe and Other Makeshift Furnaces.* Henry F. Collins. (Abstract from *Proceedings* of the Inst. of Min. and Metal.) (16) Serial beginning July 11.
The Casting of Pipeless Ingots by the Sauveur Overflow Method.* Albert Sauveur and Jasper Whiting. (Paper read before Amer. Soc. for Testing Materials.) (20) July 16.
The Swedish Lancashire Iron. Birger F. Burger. (20) July 16.
Note on the Alleged Cementation of Iron by Silicon. J. E. Stead. (Paper read before the Iron and Steel Inst.) (11) July 17.
The Cyaniding of Some Silver Ores by Percolation. Andre P. Griffiths and Frank W. Oldfield. (Abstract from *Proceedings* of the Inst. of Min. and Metal.) (16) July 18.
New Valves for Regenerative Furnaces.* (20) July 23.
Temperature Reactions in the Blast Furnace. Horace Allen. (12) July 24.
The Elmore Oil-Concentration Plant. Arthur W. Sancton. (45) Aug.
Fuel Briquetting. (45) Aug.
An Introduction to the Study of Alloys.* Henry M. Howe. (9) Aug.
The Treatment of Broken Hill Sulphides. Alec A. Readle. (16) Aug. 8.
L'Acier Thomas et Sa Fabrication.* A. de Riva-Berni. (34) Serial beginning June.
Nouvelles Récherches sur les Aciers au Nickel. Léon Guillet. (33) June 27.
Affinage de la Fonte par le Procédé Talbot: Nouvelles Applications de ce Procédé. (33) July 4.
Fabrication des Essieux en Acier Comprimé.* (33) July 11.

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Military.

The Theory and Practice of Armour Attack. (12) July 17.
Smokeless Powders; Their History and Present Classification. (19) July 25.

Mining.

Roads for Mines.* James W. Abbott. (16) Serial beginning May 16.
An Automatic Mine Car Tipple.* (13) May 21.
Electricity in French Slate Quarries.* (11) May 22.
Electric Ore-Finding System. Edward Skewes. (16) May 23.
Flume Construction.* W. C. Ralston. (Paper read before the California Miners' Assoc.) (16) May 23.
Method of Removing Overburden at the New Brothers Home No. 1 Tin Mine, Tasmania.* James B. Lewis. (16) May 30.
The Chain and the Pick Machines: A Comparison of the Two Types Coal Cutters from the Standpoint of an Advocate of Chain Machines.* H. S. Johnson. (45) June.
Peculiar Mines and Ore Deposits of the Rosita and Silver Cliff Mining District of Colorado.* A. M. Welles and Arthur Lakes. (45) June.
Sinking by the Freezing Method and Its Difficulties. (22) June 5.
On Coal-Cutting by Machinery. Owen Hughes. (Paper read before the Manchester Geological and Mining Soc.) (22) June 5; (57) Serial beginning June 12.
Observations on Gold Deposits. Chester Wells Purington. (16) Serial beginning June 6.
Methods and Values on the Yukon.* John D. McGillivray. (16) June 13.
Test Drilling on the Mesabi Iron Range.* Kirby Thomas. (16) June 13.
Electrical Apparatus in Coal Mining. S. B. Belden. (27) June 20.
Dusty Shots as a Factor in Coal Dust Explosions. Henry S. Munroe. (16) June 27.
The Gold-Bearing Gravels of Alaska.* John D. McGillivray. (9) July.
The Geology of Minnesota. C. W. Hall. (45) July.
Mining in South Africa. J. H. Curle. (16) Serial beginning July 11.
The Bottom Levels at Cripple Creek. Geo. J. Bancroft. (16) July 18.
Gold Pan Mining Plant at Breckenridge, Colo.* (27) July 18.
Discovery and History of the Witwatersrand Gold Fields. H. H. Webb. (Abstract of paper read before the South African Assoc. of Engrs.) (68) Serial beginning July 25.
Transverse Winding Engines for Deep Shafts.* H. M. Morgans. (Paper read before the Inst. of Min. and Metal.) (68) Serial beginning July 25.
Prospecting and Valuing Dredging Ground with a Well-Driller at Oroville, Cal. Newton Booth Knox. (Paper read before Inst. of Min. and Metal.) (13) July 30.
Electric Power Appliances in the Mines of Europe.* Émile Guarini. (9) Aug.
Safety Mining Lamps.* Rufus J. Foster. (3) Aug.
Water in the Mines of Cripple Creek.* Victor G. Hills. (16) Aug. 8.
L'Exploitation des Carrières aux États-Unis. A. De Gennes. (32) Mar.
Haveuses Mécaniques Employées dans les Mines de Houille.* J. Rosset. (33) Serial beginning July 4.

Miscellaneous.

Weights and Measures. S. W. Stratton. (58) Mar.
The Organization of Manufacturing Industries. Andrew Carnegie. (Extracts from Presidential address before Iron and Steel Inst.) (13) May 14; (22) May 8.
The Rockslide at Frank, Alberta.* Wm. Pearce. (13) June 4.
The Effect of Design on Methods of Construction from a Contractor's Point of View. R. W. Newman, Assoc. M. Inst. C. E. (Paper read before the Junior Inst. C. E.) (12) Serial beginning June 5.
The Training of the Civil Engineer. Geo. F. Swain, M. Am. Soc. C. E. (Extracts from article in *N. Y. Tribune.*) (15) June 12.
The Cause of the Cementing Value of Rock Powders. Allerton S. Cushman. (Abstract of paper in the *Journal* of the Amer. Chem. Soc.) (14) June 13.
The Subsidence of the Land and of the Harbor Bottom at Boston. (13) June 18.
The Making of Specifications. Chas. B. Dudley. (Presidential address delivered before Amer. Soc. for Testing Materials.) (13) July 9; (14) July 18; (20) July 9; (24) Serial beginning July 20.
The Heppner Disaster. John T. Whistler, Assoc. M. Am. Soc. C. E. (13) July 16.
Land Subsidence at Boston and the Reliability of Level Datum Planes. (14) July 18.
Lunette Pyrométrique à Réticule Thermo-Électrique.* Ch. Féry. (33) May 30.
Le Laboratoire d'Essais du Conservatoire des Arts et Métiers.* A. Dumas. (33) July 11.

Municipal.

The Construction of a Mountain Road in Cyprus. Edward Hugh Dyneley Nicolls, Assoc. M. Inst. C. E. (63) Vol. cli.
The Economic Construction and Maintenance of Roads in the Island of Cyprus. Charles Vincent Bellamy, M. Inst. C. E. (63) Vol. cli.
Asphalt Pavement and Street Railway Tracks.* W. Boardman Reed. (17) May 23.
The High Pressure Gas Main under the Mississippi River at New Orleans.* Thomas D. Miller. (Paper read before the Western Gas Assoc.) (24) June 8.
Brick Paving in Iowa. (14) June 13.

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Cost of Brick Pavements in Champaign, Ill. Charles Apple. (Reprinted from *The Technograph.*) (13) June 18.
Improved Streets and Their Repairs. W. F. Raymond. (60) July.
Concrete Culverts. A. W. Campbell. (Paper read before the Eng. Soc. of the Toronto School of Practical Science.) (67) July.
Sidewalk Building and Sidewalk Grades in Small Towns. Ernest McCullough. (13) July 9.
The Testing of Bitumens for Paving Purposes. A. W. Dow. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (14) July 11; (13) July 23.
Notes on Some Moderate Cost Roads.* William G. Raymond. (14) July 18.
The United States Road Material Laboratory.* Logan Waller Page and Allerton S. Cushman. (Paper read before the Amer. Soc. for Testing Materials.) (14) Serial beginning July 25.
The Back Filling of Trenches. W. F. Raymond. (60) Aug.
The Grand Boulevard and Concourse, New York City.* (14) Aug. 8.
Question d'Édilité Parisienne.* Ch. de Tavernier. (36) July 10.

Railroad.

The Limmat Valley Electric Road Railway. Charles Sheibner du Riche Preller, Assoc. M. Inst. C. E. (63) Vol. cli.
Railroad Repair Shop Design and Equipment.* George A. Damon. (61) Apr.
The Use of Timber by Railroads and Its Relation to Forestry. Hermann von Schrenk. (65) Apr.
Railroad Interest in Forest Supplies. B. E. Fernow. (65) Apr.
Injectors as They Are Met With in Every Day Railway Practice. F. W. Edwards. (61) May.
Express Engine, Western Railway of France.* (12) May 15.
Suburban Locomotive Development.* (15) May 15.
Metal Ties in Germany.* (15) May 15.
A New Electric-Motor Signal.* (15) May 15.
Water for Locomotive Boilers. William M. Jewell. (15) May 15.
The Appleyard Syndicate's Interurban System.* (17) Serial beginning May 16.
Tandem Compound for the New York Central.* (40) May 15.
New DeWitt Roundhouse of N. Y. C. & H. R. R. R.* (18) May 16.
Valtellina 20 000 Volt Three-Phase Electric Railway in Italy.* (18) May 16.
The Electrification of the Mersey Railway.* (47) May 16.
Location and Construction of the Ohio Residency, Pittsburg, Carnegie & Western R. R.* (13) May 21.
A New Automatic Buffer Coupling.* Charles Rous-Marten. (12) May 22.
The Sonder Steel Coke Car.* (40) May 22.
Temperature Tests of Injected Water (Locomotives).* H. M. Wickhorst. (40) May 22.
Switching Locomotives, Pittsburg, Shawmut & Northern Railroad.* (40) May 22.
New Passenger Locomotives for the Chicago & Alton Ry.* (13) May 28.
The Valtellina Electric Railway. Émile Guarini. (40) May 29.
Steam Distribution of the Vauclain Compound Locomotive.* Lawford H. Fry. (From the Baldwin Locomotive Works' "Record of Recent Construction," No. 42.) (15) May 29.
The Three-Phase Railway at Valtellina.* (17) May 30.
The Proposed Terminal at St. George, Staten Island.* (17) May 30.
Six-Coupled Bogie Express Engine (Class 4-6-0); Great Western Railway.* (21) June.
Leaky Flues and Circulation in Wide Firebox Locomotives. John Player. (25) June.
Lignite Burning in Locomotives, Burlington & Missouri River Railroad: Analysis of Smokebox Gases. M. H. Wickhorst. (25) June.
Steel-Frame, Side-Door, Suburban Passenger Cars; Illinois Central Railroad.* (25) June.
Steel Frames for Cars: A Steel Frame Box Car.* C. A. Seley. (25) June.
Compound Passenger Locomotives, 4-4-2 Type; Vauclain Four-Cylinder Balanced System, Atchison, Topeka & Santa Fé Railway.* (25) June.
Steel Underframes and Steel Cars. (25) June.
New Roundhouse of the Baltimore & Ohio Railway.* (39) June.
Freight Locomotives of the Kansas City Southern Railway.* (39) June.
Line Changes on the Rio Grande Western Ry. in Utah.* W. P. Hardesty. (13) June 4.
Electro-Pneumatic Interlocking Plant. (11) June 5.
Clayton's Fog-Signalling Apparatus.* (11) June 5.
Eight-Wheeled Coupled Compound Locomotive for the Mediterranean Railway Company, Italy.* (11) June 5.
The Hall Electro Gas Signal.* (15) June 5.
Electrical Installation for Suburban Traffic on the North Eastern.* (15) June 5.
Superheated Steam in Locomotive Service. (15) Serial beginning June 5.
Compound Consolidation Locomotive for the Southern Pacific.* (40) June 5.
Maintenance of Boilers and Roundhouse Work. Reynold C Young. (Presented in Columbus Convention, International Ry. Master Boilermakers' Assoc.) (18) June 6.
New Electric Railroad from Paris to Versailles.* (19) June 6.
Gillmor's Automatic Switch Lock.* (15) June 12.
Steel Tandem and Twin Spring Draft Gears.* (15) June 12.

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The Forsyth Automatic Air and Steam Coupling.* (15) June 12.
Heavy Eight-Wheel Passenger Engines for the Delaware & Hudson.* (40) June 12.
Electric Locking for Levers of Interlocking Machines.* (40) June 12.
The Lackawanna & Wyoming Valley Railroad.* (14) June 13; (40) June 19.
Electric Interurban for Freight and Passengers (Lackawanna & Wyoming Valley).* (17) June 13.
The Electric Lighting of a Few Steam Trains of the Prussian Railroads.* (18) June 13.
The Standard Code on the C., N. O. & T. P. (15) June 19.
Tendencies in Locomotive Design.* (15) June 19.
Trucks for High Speed Electric Railroads.* (15) June 19.
A Remarkable Iowa Interurban.* (17) June 20.
Electrical Traction on the North-Eastern Railway of England.* (17) June 20; (12) July 24.
Pennsylvania R. R. Standard Passenger Locomotives.* (18) June 20.
New St. Paul Shops of Great Northern Railway.* (18) June 20; (15) June 19.
The Perfect Contact System of Electric Traction.* (47) June 20.
German Tests of Railway Train Resistance. (13) June 25.
New York Central Passenger Locomotive.* (11) June 26.
Milwaukee Shop Improvements of the Chicago, Milwaukee & St. Paul.* (15) June 26.
The Internal Combustion Engine in Railroad Service. (Abstract of paper presented to the Master Mechanics' Convention.) (15) June 26; (18) June 27; (25) Aug.; (62) Aug. 6.
The Symington Dust Guard.* (15) June 26.
Modern Steel Cars.* (15) June 26.
Steel Coke Cars for the Pennsylvania Lines West.* (15) June 26.
Fast Freight Engines for the Lackawanna.* (40) June 26.
Improvements on the Cleveland & Southwestern Interurban System.* (17) June 27.
English Interurban Line (Portsmouth to Horndean).* (17) June 27.
New Weed-Burning Cars. C., M. & St. P. Ry.* (18) June 27.
Chicago, Milwaukee & St. Paul Improvements at West Milwaukee, Wis.* (18) June 27.
The Schoen Solid Forged and Rolled Steel Wheel.* (18) June 27.
The Automobile and the Railway as Transport Agents. Sylvester Stewart. (9) July.
The Design of Permanent Way and Locomotives for High Speeds. J. C. Inglis, M. Inst. C. E. (Read at the Engineering Conference, London.) (21) July.
15-Ton Bogie Fish Wagons: Great Central Ry.* (21) July.
The Van Dyke Tank Wagon.* (21) July.
Siemens' Electric Governing Gear for Pneumatic Brakes.* (21) July.
Express Passenger Engine "Atlantic Class": Great Northern Railway.* (21) July.
Boiler with Belpaire Fire-Box and Coned Barrel: Great Western Railway.* (21) July.
American Railway Master Mechanics Association: Abstracts of Committee Reports.* (39) July.
Master Car Builders' Association: Abstracts of Committee Reports. (39) July.
The Rolling and Structure of Steel Rails. P. H. Dudley. (Report to W. J. Wilgus, Fifth Vice-President, N. Y. C. & H. R. R. R.) (62) Serial beginning July 2.
Heavy Special Type Passenger Locomotive.* (12) July 3.
The Norfolk & Western Railroad.* Geo. L. Fowler. (15) Serial beginning July 3.
The Seasoning of Tie Timber.* Hermann von Schrenk. (Bureau of Forestry Bulletin.) (15) Serial beginning July 3.
Boston & Maine's Latest Passenger Equipment.* (40) July 3.
Automatic Signal Protection for Milwaukee Passenger Station, Chicago, Milwaukee & St. Paul Railway.* (40) July 3.
Methods for Winter Railway Location and Construction.* E. H. Drury. (14) July 4.
The Electrification of British Railways.* (17) July 4.
Recent Improvements in Boiler Design.* (Abstract of report of Committee to Ry. Master Mechanics' Assoc.) (18) July 4; (47) July 18.
Steam and Air Line Connections. (Report of Committee to Master Car Builders' Assoc.) (18) July 4.
Standard Requirements for High-Speed Foundation Brake Gear for Passenger Service.* (Report of Committee to Master Car Builders' Assoc.) (18) July 4; (25) Aug.
Consolidation Locomotive for Southern Railway.* (18) July 4.
Collarless Journals. (Report of Committee to Master Car Builders' Assoc.) (18) July 4.
Government Ownership of Railways. H. R. Meyer. (40) Serial beginning July 10.
Ten-Wheel Compound Locomotive for the Chicago & Eastern Illinois.* (40) July 10.
Tank Cars.* (Report of Committee of Master Car Builders' Assoc.) (40) July 10.
Report of Committee to Master Mechanics' Assoc.: Piston Valves. (18) July 11.
Locomotive Front Ends. (Report of Committee to Master Mechanics' Assoc.) (18) July 11.
Results Observed upon the Philadelphia & Reading Ry. in Connection with Inspection of Steel Rails.* Robert Job. (Paper read before Amer. Soc. for Testing Materials.) (13) July 16; (20) July 16.
The "Crewe" System of Electrically-Operated Points and Signals.* (11) July 17.
McBride's Locomotive Feed Water Heater.* (15) July 17.
The Cutting and Laying of Ties.* Hermann von Schrenk. (15) July 17.
The Electric Railways on Long Island.* (17) July 18.

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The System of the Northern Texas Traction Company.* (17) July 18.
The New La Salle Street Station in Chicago.* (18) July 18.
Foundation Brake Rigging. Henry Kolseth. (Paper read before New England R. R. Club.) (15) July 24.
Electro-Pneumatic Interlocking at Solvay, N. Y.* (40) July 24.
The Hudson River Tunnel.* (14) July 25.
The First Third-Rail Road in Switzerland.* Henri Somach. (17) July 25.
Operation of Electric Cars in Cripple Creek District.* (17) July 25.
The Rebuilding of the Gulf & Ship Island.* (15) July 31.
Atlantic Type (4-4-2) Locomotive for the Baltimore & Ohio.* (15) July 31.
Progress of the Atlantic Avenue Improvement of the Long Island Railroad.* (15) July 31.
Atlantic Avenue Improvement on the Long Island Railroad.* (40) July 31.
The Wellman-Street Fifty-Ton Steel Hopper Car.* (40) July 31; (18) Aug. 1.
Storage Batteries on Electric Railways. Howard S. Knowlton. (9) Aug.
Specifications for Locomotive Axles and Forgings.* (Abstract of Report of Committee, Master Mechanics' Assoc.) (25) Aug.; (18) Aug. 1.
Cast-Iron Wheels.* (Abstract of Report of Committee, Master Car Builders' Assoc.) (25) Aug.
Culm Burning Passenger Locomotives; 4-6-0 Type; Delaware & Hudson Company.* (25) Aug.
The Main Shops of the American Locomotive Company at Schenectady.* (14) Aug. 1.
Denver & Northwestern Interurban Road for Hauling Coal.* (17) Aug. 1.
Electric Interurban between Columbus and Zanesville.* (17) Aug. 1.
Experiments with Steel and Reinforced Concrete Ties.* (18) Aug. 1.
Side Bearings and Center Plates.* (Abstract of Report of Master Car Builders' Committee.) (18) Aug. 1.
Train Lighting with Steam Turbines.* Geheimrath Wichert. (19) Aug. 1.
The Milan-Gallarate Electric Railway.* P. Letheule. (27) Aug. 1.
New Terminal Station at Chicago for the C., R. I. & P. Ry. and the L. S. & M. S. Ry.* (13) Aug. 6.
Stremmatograph Tests of Fiber Strains in Rails under Moving Locomotives. P. H. Dudley, M. Inst. Min. Engrs. (Paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 6; (40) July 24.
Plotting of Speed Time and Speed Distance Curves from the Acceleration Speed Curve.* L. A. Freudenberger. (27) Aug. 8.
Frein-Électro-Magnétique "Westinghouse."* George Lesourd. (32) May.
Éclairage des Voitures de Chemins de Fer au Moyen de l'Incandescence per le Gaz.* H. Giraud and G. Mauclère. (38) May.
Experiénces sur le Rendement des Locomotives.* Joseph Nadal. (38) May.
Traction Electrique dans le Tunnel de la Mersey; Chemin de Fer de Liverpool à Birkenhead.* Ch. Dantin. (33) May 16.
Création d'une Nouvelle Gare Centrale de Triage à Chicago.* (38) June.
Note sur les Postes Électriques (Système Taylor) de la Gare de Pétange (Grand Duché de Luxembourg).* Collot. (38) June.
Nouvelle Locomotive de Banlieue du "Great Eastern Railway."* R. Bounin. (36) June 25.
Chemin de Fer Électrique de Fribourg-Morat-Anet (Suisse).* H. Somach. (33) June 27.
Types Récents de Voitures des Chemins de Fer et Tramways Autrichiens.* A. Morizot. (34) July.
Essais de Pièces de Locomotives en Acier Moulé par la Compagnie du Chemin de Fer du Nord. M. Du Bousquet. (38) July.
Voitures Automotrices à Vapeur (Système V. Purrey) Construites pour la Compagnie Paris-Lyon-Méditerranée.* J. Tête. (38) July.

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Electric Tramways. Charles Hopkinson, M. Inst. C. E., Bertram Hopkinson and Ernest Talbot, M. Inst. C. E. (63) Vol. cli.
A System of Electric Lighting for Cars. James F. McElroy. (42) Apr.
The Transportation Problem of Greater New York. W. W. Wheatly. (65) May.
Progress in British Tramways. (11) May 8.
The London County Council Electric Tramways: The Construction and Equipment of the Westminster-Tooting Section.* (26) May 15; (12) May 15.
Recent Developments in High-Speed Electric Traction in Germany.* (17) May 16.
The Mersey Electric Railway.* (26) May 22.
General Electric Company's Surface Contact System.* (11) May 29.
Mechanical Traction on Tramways.* (19) May 30.
New Automatic Fender and Wheel Guard. (46) May 30.
Foundations for the Elevated Structure of the Boston Elevated Railway.* Geo. A. Kimball. (1) June.
Notes on European Tramways.* Richard McCulloch. (4) June.
An Interesting Example of Wide Arch Soft Ground Tunneling (Boston Subway Extension).* (13) June 4.
London United Tramways Power Station.* (12) June 5.

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The Electrification of the Underground (London).* Wilfred Yorke. (26) June 5.
Section 4, New York Rapid Transit R. R.* (14) Serial beginning June 6.
Recent Additions to the Generating Plant of the Montreal Street Railway.* Ralph D. Mershon. (17) June 6.
Fifty-Second Avenue Terminal in Chicago.* (17) June 6.
Conduit System of the London County Council.* (17) June 6.
London Conduit Railway System.* (27) June 13.
Hampshire Light Railways.* (26) June 19.
The Electrical Conductivity of Copper. Rollo Appleyard, A. M. Inst. C. E. (26) Serial beginning June 19.
M. C. B. Truck for Brooklyn Elevated Railway.* (17) June 20.
The 4 000-Horse Power Engines at the Third Avenue Brooklyn Power House.* (64) July.
Open Elevated Motor Car—Brooklyn Heights Railroad.* (15) July 3.
Notes on Sub-Station Practice. (17) July 4.
Transportation Facilities at the Soo.* (17) July 4.
Emergency Car and Other Wrinkles on the Orange & Passaic Valley Railway.* (17) July 4.
An Emergency Track Brake used by the United Railroads of San Francisco.* (17) July 4.
The Proposed Brooklyn Bridge Terminal and New York Municipal Building.* (13) July 9.
The Paris Metropolitan Railway.* (12) Serial beginning July 10.
Notes on the Des Moines City Railway.* (17) July 11.
Proposed Inner Circle System for Chicago.* (17) July 11.
Private Telephone System of the Manhattan Railway Company.* (17) July 11.
Station Indicators for Subway, Elevated and Other Railway Systems.* Ernest K. Adams. (27) July 11.
Power Station for the Underground Electric Railways Company of London.* (17) July 18.
Elevated Railways.* Gerald Barker. (11) July 24.
Power Brakes in St. Louis. R. P. Garrett. (15) July 24.
Milford Street Railway System.* (17) July 25.
Ventilating Railway Motors.* (17) July 25.
The Reorganization of the Condensing System of the Manhattan Station.* (64) Aug.
The Missouri River Power Station of the Metropolitan Street Railway Company, of Kansas City, Mo.* (17) Aug 1.
Tramway Conditions in America and Great Britain Compared. Chris. J. Spencer. (17) Aug. 1.
Permanent Way Construction and Maintenance. Charles A. King. (17) Aug 1.
Erection of Manhattan Valley Viaduct.* (14) Aug. 8: (20) July 30.
The Power Plant for the Metropolitan Street Railway of Paris.* Émile Guarini. (19) Aug. 8.
Traction Électrique: Prise de Courant par Contact Superficiel: Système Paul.* René Philippe. (34) May.
Le Chemin de Fer Suspendu de Barmen-Elberfeld-Vohwinkel. René Philippe. (35) Serial beginning May.
Étude Générale sur le Chemin de Fer Métropolitain de Paris. (36) Serial beginning May 25.

Sanitary.

Portslade and Southwick Drainage, 1902: Intercepting Sewer and Outfall. George Stow, Assoc. M. Inst. C. E. (63) Vol. cli.
Red River Valley Drainage Ditches; Their Repair and Maintenance.* W. R. Hoag. (1) Apr.
The Action of the Septic Tank on Acid Iron Sewage. (14) May 16.
An Investigation of a Garbage Crematory. (Extract from a report by Rudolph Hering to the Special Committee on Crematory of the City Council of Trenton, N. J.) (19) Serial beginning May 16.
Swampscott Sewerage System.* (14) May 23.
The Chicago Intercepting Sewer System.* (13) May 28.
A Difficult Sewer Crossing Under an Old Aqueduct in Brooklyn.* (14) May 30.
Water Supply in the Mutual Life Insurance Building, New York.* (14) May 30.
The Composition of Sewage in Relation to Problems of Disposal. George W. Fuller. (7) June.
Power and Pumping Stations of the New Orleans Drainage System.* William Mayo Venable. (0) June.
The Baynes Garbage Disposal Works at Buffalo. (14) June 6.
The Garbage Reduction Plant at Baltimore.* (14) June 13.
American Blower Company's New Office Building: Heating and Ventilating System.* (20) June 25; (15) July 17; (40) July 24; (14) July 25; (25) Aug.
High-Pressure Steam Heating Transmission and Electric Lighting Plant at Dresden.* Franz Köster. (14) July 4.
The Northwestern Ave. Sewer at Indianapolis, Ind.* W. Buehler. (13) July 16.
An Improved Steam-Heating System.* (13) July 23.

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On the Distribution of Sewage on Bacteria Beds. John C. Thresh and Martin Priest. (Abstract of paper read before Inst. of San. Engrs.) (12) July 24.
Concrete Sewer at Coldwater, Mich. (14) July 25
Air Heating with Radiators and a Closed Piping System. (13) July 30.
Commission Chargée de l'Étude des Questions Relatives à la Pollution des Cours d'Eau: Mission en Angleterre: Rapport de la Sous-Commission. (Belgium).* (30) June.
Assainissement des Villes. (36) Serial beginning July 10.
La Balayeuse Automatique Anti-Microbienne et l'Incinération des Ordures à New York.* Albert Reyner. (36) July 10.

Structural.

Concrete. Acheson Smith. (58) Apr.
Cement—Its Manufacture, What It Is, and How to Test It. Armin Schotte. (58) Apr.
Water Tightness in Concrete. Thos. P. Roberts. (58) Apr.
A Reinforced Concrete Floor Used in the Youngstown Car Barn. G. M. Scofield. (58) Apr.
Ferro-Concrete Warehouse at Newcastle-on-Tyne.* (67) May.
Portland Cement Manufactured from Blast Furnace Slag. C. de Schwarz. (Paper read before the Iron and Steel Inst.) (22) May 8; (57) May 15; (28) May 28; (12) May 22; (62) June 4.
Structural Details of the Medical Buildings, Cornell University.* (14) May 16.
A New System of Finishing Concrete Structures.* (13) May 21.
Paint as a Preservative of Iron from Rust. (12) May 22.
A Tall Concrete-Steel Office Building.* (14) May 23.
Grillage vs. Concrete Foundations. J. C. Hain. (18) May 23.
Sand Cement for Concrete Works Remote from Transportation Lines. (Abstract from Bulletin No. 213, U. S. Geological Survey.) Edward Duryee. (13) May 28.
A New Creosoting Process. Hermann von Schrenk. (15) May 29.
Boston Foundations. Joseph R. Worcester. (1) June.
Foundations. George B. Francis. (1) June.
Specifications for Material and Workmanship for Steel Structures.* T. L. Condron. (4) June.
Timber and Composite Roofs.* (21) Serial beginning June.
Self-Supporting Steel Stacks. R. E. Newton, Assoc. M. Am. Soc. C. E. (14) June 6.
The Bi-Centennial Memorial Buildings of Yale University.* (14) June 6.
The Aiken Improved Roof Construction for Manufacturing Plants.* (20) June 11.
The Testing of Building Stone. Edwin C. Eckel. (16) June 20.
The British Fire Prevention Committee and Its Work. (19) June 20.
The New Shops of the American Locomotive Company at Schenectady.* Lindsay Duncan. (14) June 27.
The Use of Iron Pipe in Structural Work.* Egbert P. Watson. (9) July.
Portland Cement Manufacture: The Raw Materials. Edwin C. Eckel. (60) July.
The Proposed Brooklyn Bridge Terminal and New York Municipal Building.* (13) July 9.
The Works of the St. Louis Portland Cement Company, Prospect Hill, Mo.* John E. Conzelman. (14) July 11.
A Standard Method for the Analysis of Cement. (13) July 16.
The Relative Strength of Wet and Dry Concrete. James W. Sussex. (Reprinted from the *Technograph.*) (13) July 16.
A Table for Pitch and Efficiency of Riveted Joints. Philip B. Hill. (13) July 16.
The Erection of a Tall Concrete Office Building (Ingalls Bldg., Cincinnati).* (14) July 18.
The Steel Manufacturers' Standard Specifications. Albert Ladd Colby. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (14) July 18; (62) Serial beginning Aug. 6.
The Plant of the Hudson Portland Cement Co., at Hudson, N. Y.* (13) July 23.
Soundness Tests of Portland Cement.* W. P. Taylor, Jun. Am. Soc. C. E. (Paper read before Cement Section, Amer. Soc. for Testing Materials.) (13) July 23.
International Fire-Prevention Congress. (11) July 24.
The New York Shipbuilding Company's Plant, Camden, N. J.; Pt. II.* (14) July 25.
American Blower Company's New Office Building.* (14) July 25.
Sixteen-Story Concrete-Steel Office Building at Cincinnati, O.* (13) July 30.
The Strength of Concrete as Affected by Different Percentages of Water. T. L. Doyle and E. R. Justice. (13) July 30.
Tests of Portland Cement Mortar Exposed to Cold. C. S. Gowen, M. Am. Soc. C. E. (Paper read before Amer. Soc. for Testing Materials.) (13) July 30.
Rational Formulas for the Strength of a Concrete-Steel Beam. S. E. Slocum. (13) July 30.
Rivets in Structural Steel Work.* C. J. Tilden, Assoc. M. Am. Soc. C. E. (Reprinted from *Harvard Engineering Journal.*) (13) July 30.
The Main Shops of the American Locomotive Company at Schenectady.* (14) Aug. 1.
Effect of Water and Combinations of Sand on the Setting and Strength of Cement. E. S. Larned. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 6.

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The Cause of the Cementing Value of Rock Powders and the Plasticity of Clays. Allerton S. Cushman. (Abstract of paper read before the Amer. Soc. for Advancement of Science.) (13) Aug. 6.
Preservation of Wood. (Translated from *La Chronique Industrielle.*) (19) Aug. 8.
Note sur les Cables Témoins: Système F. Arnodin. F. Arnodin. (32) Mar.
Les Sables Boulants: Méthodes Nouvelles de Constructions dans les Terrains Aquifères.* A. Casse. (30) June.
Essai d'une Théorie des Voûtes d'Égale Résistance. Maurice Astier. (35) Serial beginning June.
La Nouvelle Caserne de Sapeurs-Pompiers de la rue Carpeaux.* M. Marchand. (33) June 6.
Le Nouveau Pavillon du Pesage de l'Hippodrome de Longchamp.* Couraud. (36) June 10.
La Méthode Chartiée pour l'Essai au Choc des Aciers Laminés.* Léon Griveaud. (34) July.
Pavillon de Chirugie à l'Asile Clinique Sainte-Anne, rue d'Alésia, à Paris.* Ed. Perronne. (35) July.
Fabrique de Ciment Portland de Rudelsbourg (Saxe).* (35) July.
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INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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TESTS OF THE EFFICIENCY OF HOISTING TACKLE.

By S. P. Mitchell, M. Am. Soc. C. E.

To be Presented September 16th, 1903.

For the purpose of gaining information as to the efficiency of hoisting tackle, an extended series of tests was made recently at the Pencoyd plant of the American Bridge Company, with standard types of blocks, and various combinations of manila and wire rope. The tests were arranged so as to reproduce, as nearly as possible, actual conditions under which hoisting tackles are used in the field.

An eye-bar testing machine, of 300 tons capacity, and a vertically-moving hydraulic crane, were used in making the tests. One block was attached to the fixed head and one to the movable head of the machine, the latter having a horizontal motion, under constant pressure, of about 6 ft. The line was led, as shown in Fig. 1, from the movable block to a snatch block at the fixed end of the machine, thence, with a 180° turn, to a second snatch block, thence, with a 90° turn, to a vertically-moving hydraulic crane, which furnished the lead-line pull.

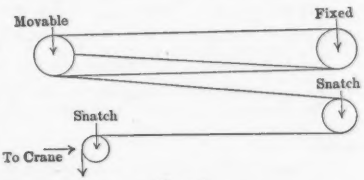


Fig. 1.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The load registered on the testing machine was thus carried on as many parts of line as ran to the movable block, this number being one in excess of that leading to the fixed block.

The load on the machine, and the pull exerted by the crane, were taken from their respective mercury pressure gauges, upon which many simultaneous readings were made for each individual test. Separate readings, of course, were taken to determine the friction of the testing machine and crane.

Each combination of tackle was tested in lifting, *i. e.*, with the movable block approaching the fixed block, as in lifting a load; and for a becket pull, *i. e.*, with the movable block receding from the fixed block, as in lowering a load. The results of these tests are shown in Table No. 1. The tested efficiencies there given are derived as follows: If W be the load on the machine, n the number of parts of line carrying the load, and P the pull of the crane, the tested efficiency for straight lifts is $\frac{W}{n P}$.

For the becket pulls, in which the machine is pulling against the crane, an analogous value for efficiency is $\frac{n' P'}{W'}$; where W' is the pull of the machine, n' the number of parts of line, and P' the resistance of the crane. It should be noted that the results of the individual tests, as given in the column of tested efficiencies, are each derived from a large number (in most cases forty to fifty) of gauge readings.

Under field conditions, a lead-line is frequently snatched a number of times before reaching the engine. It was desired, therefore, to obtain results of the tests, free from the influence of the two snatch blocks used, and involving only the parts of the line holding the load, of which the first should be considered the lead-line, as shown in Fig. 2.

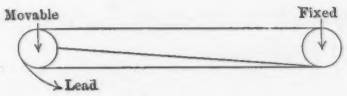


FIG. 2.

For this purpose the efficiencies of the combinations tested were worked out according to the method given by Weisbach.*

The formula there used for the efficiency of a fixed pulley is

$$\frac{1}{K} = \frac{1}{1 + C\frac{d^2}{r} + 2\ \sigma\frac{P}{r}\sin. L}$$

* The Mechanics of Hoisting Machinery." Translated from the second German edition by Karl P. Dahlstrom, M. E.

In which d = diameter of rope;

r = effective radius = distance from center of pulley to center of rope;

P = radius of sheave pin;

$2L$ = arc of contact of rope on sheave;

$\acute{o}$ = coefficient of journal friction = 0.08;

C = empirical constant.

The efficiency of the movable pulley, for forward motion, or lifting, is $\frac{1+K}{2K}$.

For reverse motion, or becket pull, it is $\frac{2}{1+K}$.

It was found that a constant value of C did not give computed efficiencies agreeing sufficiently well with those of the tests. Accordingly, different values of C were selected for the different sizes of rope. These are given in Table No. 1, together with the efficiencies computed from the formula.

The constant, C, for $\frac{3}{4}$-in. wire rope, was derived from the tests on 7, 9 and 13 parts of line, as the friction of the testing machines in the tests on 3 and 5 parts of line was so large in proportion to the load lifted as to render the results of the two tests of doubtful value.

Table No. 3 contains the essential dimensions of the blocks tested.

Having determined a suitable value of C for each size of line, it only remained to compute the efficiencies of the several combinations, omitting the snatch blocks.

The results are shown in Table No. 2, together with the lift of each combination per unit pull in lead-line; the lead being, as explained previously, the first part of the line holding the load.

The tests were in charge of J. L. de Vou, Assoc. M. Am. Soc. C. E., Assistant to the Chief Engineer, assisted by Mr. S. L. Wonson, Assistant Engineer.

TABLE No. 1.—Efficiency of Tackle with Two Snatch Blocks.

	Parts of line.	Tested Efficiency: Percentage.				Efficiency, from Formula.	
		Lifting.	Mean.	Becket pull.	Mean.	Lifting.	Becket pull.
1¼-in. manila line. C = 0.46.	4	60, 60, 56, 57, 55, 53	57	37, 42, 50, 56, 57, ..	48	60	58
	6	52, 51, 53, 52, 52	52	56, 50	53	53	53
	7	44, 48, 52, 51	49	41, 46	44	50	45
1½-in. manila line. C = 0.40.	4	52, 48	50	47, 50	49	56	55
	7	46, 46	46	42, 43, 43	43	47	42
	9	48, 48, 56, 52, 52, 43, 43, 43, 41	47	40, 37, 38	38	42	36
1¾-in. manila line. C = 0.38.	5	45, 47, 44	45	48, 49, 49	49	47	45
	7	39, 42, 41	41	43, 33, 42	40	42	37
	9	37, 41, 39	39	34, 33, 36	34	37	31
2-in. manila line. C = 0.34.	7	39, 41, 44	41	32, 38, 37	36	40	36
	9	36, 38, 39	37	37, 37, 39	38	35	30
¾-in. wire rope. C = 1.8.	3	47, 48, 46	..	42, 47, 40, 35	....	....	....
	5	49, 48, 49	49	42, 41, 42	41	....	....
	7	49, 50, 49	49	46, 45, 41	44	55	56
	9	53, 58, 55, 49	54	41, 44, 43	43	50	49
	13	43, 44, 48, 46	45	53, 51, 51, 54	52	42	37

TABLE No. 2.—Capacity and Efficiency of Tackle without Snatch Blocks.

	Parts of line.	Lift per unit pull in lead-line.	Efficiency: Percentage.
1¼-in. manila line	2	1.92	96
	3	2.68	89
	4	3.37	84
	5	3.95	79
	6	4.48	75
	7	4.92	70
1½-in. manila line	2	1.91	96
	3	2.67	89
	4	3.36	84
	5	3.93	79
	6	4.45	74
	7	4.89	70
	8	5.28	66
	9	5.61	62
1¾-in. manila line	3	2.64	88
	4	3.30	83
	5	3.84	77
	6	4.33	72
	7	4.72	67
	8	5.08	64
	9	5.37	60
2-in. manila line	5	3.87	77
	6	4.37	73
	7	4.78	68
	8	5.14	64
	9	5.45	61
¾-in. wire rope	3	2.73	91
	4	3.47	87
	5	4.11	82
	6	4.70	78
	7	5.20	74
	8	5.68	71
	9	6.08	68
	10	6.46	65
	11	6.78	62
	12	7.08	59
	13	7.34	56

TABLE No. 3.—Dimensions of Blocks Used in Tests.

Metaline bushed.	Center of sheave pin to tread of sheave.	Diameter of sheave pin.
12-in. blocks for 1¼-in. manila line	3¼ ins.	⅞ in.
14-in. blocks for 1½-in. manila line	3 11/16 "	1 in.
16-in. blocks for 1¾-in. manila line	4½ "	1⅛ ins.
20-in. blocks for 2-in. manila line	5½ "	1⅜ ins.
Snatch blocks for manila line	3⅝ "	1 in.
Wire-rope blocks	7 "	2½ ins.

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SOUTH AFRICAN IRRIGATION.

By Francis Robert Johnson, M. Am. Soc. C. E.

To be Presented October 7th, 1903.

The Present Position of Irrigation.

In South Africa it may be said that the limit of private enterprise in the construction of irrigation works has only been reached as far as leading the ordinary flow of the smaller streams is concerned. The ditches, or furrows, as they are called, in many cases have been made by the farmers without any levels, the usual procedure being to test the furrow, as construction proceeds, by letting the water follow up the work. The result is that the fall is generally insufficient, and a great deal of silt is deposited at flood time.

As a rule, a loose rock weir, from 1 to 5 ft. high, as required, is thrown across the stream at the point of intake. The following are typical colonial furrows, the figures having been determined by the writer from actual survey.

Case 1.—Length, 5 miles. Flow into river near fields, in average condition, 1.98 cu. ft. per second. Waters, 616 acres. Flow of river, observed during one summer: minimum, 11 cu. ft. per second; maximum, 1 280 cu. ft. per second. Fall of river, about 20 ft. per mile. Greatest known flood, about 5 800 cu. ft. per second. Catchment area, 239 sq. miles. Average annual rainfall at source, 50.71 ins.;

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and, in vicinity of fields, 21.06 ins. Seasonal rainfall: Spring, 4.73 ins.; summer, 8.82 ins.; autumn, 5.56 ins.; winter, 1.95 ins. Wheat is largely grown from the middle of March to the middle of December, during which period the rainfall averages 11.75 ins., which is supplemented by irrigation. Other crops are maize, Kaffir corn and potatoes.

Case 2.—A group of five furrows. Maximum length, about 7 miles. Average combined flow near fields, during three summer months, 4.33 cu. ft. per second, or 17 000 000 cu. ft. for the whole summer, exclusive of the night flow which is seldom used. Waters 718 acres, all the year, and an additional 350 acres in the winter during good seasons. Flow of river, observed during one summer: minimum, 0.07 cu. ft. per second; maximum, 1 378 cu. ft. per second. Fall of river, about 45 ft. per mile. Greatest known flood, about 5 200 cu. ft. per second. Catchment area, 68 sq. miles. Average annual rainfall at source, 23.25 ins., and in vicinity of fields, 7.21 ins. Seasonal rainfall: spring, 2.02 ins.; summer, 1.43 ins.; autumn, 2.76 ins.; winter, 1.00 in. Lucerne is largely grown as food for ostriches; other crops are tobacco, wheat, barley, maize, beans, vines and fruits.

There is considerable irrigation from springs or "fountains," as they are called, but, unfortunately, there are no statistics of any kind available, and even in the case of furrows there is only a very partial record which refers mostly to those used for village water supplies. The finding and opening up of two of these "fountains" will now be described, as they are rather interesting. In both cases the sites were inspected and the details noted and checked on the ground, as far as possible.

Case 3.—A farmer purchased a farm of 4 000 acres on which there was no water. After a time he noticed signs of moisture in a hollow, which he therefore plowed over regularly so as to assist the summer thunderstorms in forming a sluit (stream) and opening up the ground. This resulted in the rock being laid bare, eventually, at a depth of 20 ft. from the surface, and, as the flow of water was then stronger, and a trap dike ran across the country just below, he decided to have bores put down.

Four 2⅛-in. bore holes were drilled 40 ft. into the rock, and iron pipes were laid from them to a small reservoir near to, and commanding the cultivated ground; the pipes being 2 ins. in diameter and having a considerable slope. The flow, in all, is said to be equal

to 160 000 galls. in 24 hours, say 25 600 cu. ft. In 10 days this would enable 50 acres to get a watering of 1¼ ins.

The farmer uses this supply over an area of 140 acres, and says it is enough to provide against drought, and save the crops in bad seasons, while it increases the yield very much in good seasons.

Case 4.—A farmer, in this case, also, noticed moisture above a trap dike, and excavated what in appearance is a miniature railroad cutting, with slopes of about ½ to 1, formation width 2 to 3 ft., and depth about 10 ft. to the rock. Three holes, about 1½ ins. in diameter, were bored in the rock to a depth of only 6 ft., and from each hole water boils up to a height of several inches, and runs down the cutting to a small reservoir, where it is stored.

There are a great many of these fountains, both in the Cape and Orange River Colonies, and it is believed there are also a good many in the Transvaal.

Many farms have one or more small reservoirs to catch surface water. To avoid risk, these are usually located as near the watershed as possible, consistent with getting a catchment at all. These are sometimes used for watering cattle, and sometimes to irrigate gardens. Very few hold as much as 500 000 cu. ft.

Occasionally, dams are thrown across a well-defined stream, but owing to defective design and construction, or want of an adequate waste weir, many of these have burst, and their ruins can be seen in many parts of the country.

Successful storage works, of any magnitude, for irrigation, are very scarce. There are also very few wells used for irrigation in the Cape or Orange River Colonies; but in Natal the free Indians, mostly from Madras and Bengal, have excavated some, and lift the water with picotahs to irrigate their small patches of ground, on which these industrious people raise very fine vegetables. To sum up, it may be said that leadings have only been taken from the smaller streams which run near the surface of the country, and hardly at all from the larger ones and those which run at a considerable depth below the surface, while wells and large storage works for irrigation are almost unknown.

Geology.

The geology of South Africa is somewhat puzzling, as it has not yet been worked out thoroughly, and, indeed, cannot be until a better

map is available. In addition, many contradictory statements, based on hurried visits to the country, have been made by geologists, and these have only served to complicate matters.

As far as known, intrusive granite rocks appear to form the basement of the country. They are exposed at Cape Town at the sea level, in contact with the overlying series of slates and compact quartzites, called, in the Cape, "Malmsbury beds," which are the oldest, known sedimentary rocks thus far discovered.

Again, in the Transvaal, at an elevation of some 5 800 ft., granite is exposed here and there over considerable areas north of Johannesburg. It is also exposed at the base of the Drekensburg Range in the De Kaap Valley, and in the bed of the Letaba River, north of the Murchison Hills.

It would appear that there was considerable denudation throughout the country, followed by upheaval and then by more denudation; also, that the denudation increased from north to south, and that the débris traveled southward. As a result of the general upheaval, the slates and quartzites, not only in the Cape, but in the Orange River Colony and the Transvaal, have generally a very high angle of dip.

Peculiar throughout South Africa are the intrusive trappean dikes, which penetrate, not only the granites and the slates, but other formations, although, thus far, they have not been noticed in the Table Mountain sandstones, a series of rocks at the Cape which lies unconformably on the upturned edges of the Malmsbury beds. Locally, where these trappean dikes have been intruded, and they are very numerous indeed, there has been, naturally, much disturbance and alteration in the overlying rocks. The dikes are generally diabase and dolerite in the Cape, but are said to be mostly diorites in the Transvaal.

The slates, generally speaking, are rotted to a considerable depth. The writer has found this to be the case 30 ft. from the surface, and streams running over these rocks often disappear, only to reappear at some intrusive trap dike which bars the way to further underground movement of the water. The late W. H. Furlonge, M. Am. Inst. Min. Engrs., mentions* that the granite of the De Kaap Gold Fields is decomposed to a depth of 200 ft.

* *Transactions*, Am. Inst. Min. Engrs., Vol. XVIII, 1890, p. 337.

In the usually flat-bedded series of rocks, such as the sandstone series, and the coal formation, alternate hard and soft layers are very common, and in many of the streams which flow over these rocks the writer has noticed that the bed has been more or less blown up, owing to the water getting into a soft layer below the surface.

It is difficult at present to say much as to the proper sequence of the rocks which lie above the Malmsbury beds at the Cape, and above the slates in the Transvaal, because the geology of all the colonies has not yet been treated as a whole, but it may be said that these rocks are often much altered and contorted as a result of the dynamic movements which have taken place, and that the origin of some of them has not yet been accounted for satisfactorily. It may be mentioned, however, that while, in the Cape, the Table Mountain sandstones lie unconformably on the upturned edge of the Malmsbury beds, in the Transvaal it is stated that the sandstone series there lies conformably on the slates.

The soil covering, on the whole, is thin and poor in quality. There are exceptions, of course, but, comparatively speaking, these are of small area, and are scattered widely. It is probable that, as in many other countries, for instance, the United States of America, the soils of the arid districts, particularly in the Cape and Orange River Colonies, will be found to be the most fertile; indeed, in the Cape Karoo the writer has noticed this fertility as being most marked in the few places where water has been applied. To a great extent this is, doubtless, due to the presence of lime and various salts in considerable quantities which the scanty rainfall has been unable to wash out. The lime is in the form of a very fine powder, and is conspicuous to the eye.

The following difficulties are likely to present themselves to the hydraulic engineer, in many cases:

1.—Indifferent foundations for large masonry dams.

2.—Scarcity of good puddle.

3.—Leaky reservoirs and canals.

In the writer's opinion, the method of construction for storage works most suited to the country, on the whole, will be found to be concrete core-walls carried well down, with rock-filled outer slopes and inner slopes of earth, not only from the geological point of view, but from the economical one also.

The Seasons.

The seasons are opposite to those of Europe, viz.:

Spring: September, October, November;

Summer: December, January, February;

Autumn: March, April, May;

Winter: June, July, August.

The mean temperatures at typical places in the Colonies, during the various seasons, in the year 1899, are shown in Table No. 1.

TABLE No. 1.—Mean Temperature at Typical Places in the Colonies During the Various Seasons of the Year 1899.

Place.	Colony.	Elevation.	Spring.	Summer.	Autumn.	Winter.
			°	°	°	°
Port Elizabeth.....	Cape Colony..	Sea Level.	62.1	69.6	65.3	59.9
Somerset East.....	Cape Colony..	2 400 ft.	62.7	71.6	63.4	56.1
Steynsburg	Cape Colony..	4 850 ft.	60.9	70.3	57.2	48.4
Durban.....	Natal.....	Sea Level.	71.6	77.8	70.3	67.4
Maritzburg.....	Natal.....	2 218 ft.	66.8	72.7	64.9	59.4
Ladysmith.....	Natal.....	3 284 ft.	69.8	75.8	65.8	53.1
Bloemfontein.....	Orange River.	4 518 ft.	65.2	74.4	59.5	50.6
Johannesburg.....	Transvaal	5 735 ft.	....	....	58.4	51.8

In Maritzburg, Natal, the winter temperature would ripen cereals if the days were long enough, as it exceeds the summer temperature of Calgary, Alberta, in the Dominion of Canada, the latter being only 58.8 degrees. At Calgary, wheat and oats ripen in this temperature, which shows the potent effect of light, as there are 17 hours of daylight at Calgary, as compared with some 11 to 12 hours during the winter at Maritzburg.

The Rainfall.

Tables Nos. 2 and 3 give the seasonal and annual rainfall for places located along the drainage lines of the country.

These records have been compiled by the writer from various sources and speak for themselves in showing how much irrigation is needed; but, if all the variations from the mean could have been shown, they would have afforded a still more potent argument.

TABLE No. 2.—Rainfall in Cape Colony.

Hydrographic district No.	Main river.	Source.	Average Rainfall, in Inches.					Number of years in period.	Midway.	Average Rainfall, in Inches.					Number of years in period.
			Seasonal.				Annual.			Seasonal.				Annual.	
			Spring.	Summer.	Autumn.	Winter.				Spring.	Summer.	Autumn.	Winter.		
1	Buffels	Garies	1.31	0.29	1.80	2.43	5.74	7	Springbokfontein	1.99	0.84	3.32	3.59	9.74	10
2	Breede	Ceres	9.35	2.45	11.85	18.00	41.65	10	Robertson	3.56	2.08	3.38	4.01	18.03	10
2	Great Berg	Wellington	5.17	1.88	7.31	11.22	25.18	10	Piquetberg	6.05	1.40	6.02	8.89	22.36	10
2	Olifants	Matjesfontein	1.52	1.27	1.97	1.67	6.43	10	Clanwilliam	2.16	0.78	2.75	3.72	9.41	10
3	Hartebeest	Sutherland	2.38	1.82	3.46	2.35	10.01	10	Rhebooksfontein	1.45	2.21	2.43	1.02	7.11	6
4	Gouritz	Beaufort West	2.53	3.51	2.96	0.74	9.74	10	Calitzdorp	2.08	1.58	2.91	1.29	8.40	10
5	Sundays	Graaf Reinet	5.29	5.86	5.85	1.76	18.76	10	Jansenville	3.39	4.46	4.09	1.13	13.07	10
5	Gamtoos	Brakfontein	2.36	4.30	4.16	0.44	11.76	10	Willowmore	2.47	3.26	3.89	1.42	11.04	10
6	Brak	Victoria West	2.48	5.43	3.35	0.80	12.06	10	Bristown	2.61	3.49	4.86	1.09	12.05	7
7	Kraal	Molteno	5.87	7.02	9.53	5.98	27.70	6	Barkly East	6.46	11.20	7.65	3.05	28.31	10
7	Sea Cow	No record							Boschfontein	3.61	4.65	5.02	1.17	14.45	3
8	Steynsburg		4.20	7.88	6.10	2.10	20.28	10	Witmoss	4.57	6.29	5.29	2.06	18.21	10
9	Great Kei	Sterkstrom	5.36	9.74	6.23	2.46	23.79	13	Kelands	7.90	10.35	6.96	2.25	27.06	6
10	Umzimvubu	Mount Fletcher	11.06	14.86	7.73	1.56	35.21	3	Gumba	10.27	12.96	8.63	2.35	34.11	6
11	Malopo	No record							No record						
12	Groen Water	No record							Griquatown	2.61	6.92	5.02	1.44	16.59	10
12	Harts	No record							Vryburg	2.48	16.04	5.75	1.23	25.50	4

TABLE No. 3.—Rainfall in Orange River, Transvaal and Natal Colonies.

Hydrographic district.		Average Rainfall, in Inches.					Length of record, in years.		Average Rainfall, in Inches.					Length of record, in years.
		Seasonal.				Annual.			Seasonal.				Annual.	
		Spring.	Summer.	Autumn.	Winter.				Spring.	Summer.	Autumn.	Winter.		
ORANGE RIVER COLONY.														
Caledon River	Midway—Ladybrand	8.44	14.32	8.62	3.02	34.41	8	Outfall—Bethulie	4.25	9.00	6.19	2.36	21.80	8
Riet River	Midway—No record	.....	.....	.....	.....	.....	....	Outfall—Jacobsdal	3.82	7.97	6.25	1.72	19.76	10
Modder River	Midway—Bloemfontein	5.58	10.08	7.89	1.84	25.39	10	Outfall—Jacobsdal	3.82	7.97	6.25	1.72	19.96	10
Zand River	Midway—No record	.....	.....	.....	.....	.....	....	Outfall—Hoopstad	4.35	12.22	5.87	0.91	23.35	4
Valsch River	Midway—Kroonstad	6.73	11.85	7.57	1.02	27.17	10	Outfall—No record	.....	.....	.....	.....	.....	....
Rhenoster River	Midway—No record	.....	.....	.....	.....	.....	....	Outfall—No record	.....	.....	.....	.....	.....	....
Wilge River	Source—Harrismith	8.94	12.28	6.38	1.54	29.14	5	Midway—No record	.....	.....	.....	.....	.....	....
Klip River	Source—Newcastle	5.39	17.89	6.69	0.42	30.39	3	Midway—No record	.....	.....	.....	.....	.....	....
TRANSVAAL COLONY.														
.....	Johannesburg	6.25	16.25	6.50	0.75	29.75	11	.....	.....	.....	.....	.....	.....	....
NATAL COLONY.														
Umzimkulu River	Midway—Umzimkulu	8.68	11.98	6.02	1.72	28.40	9	Outfall—Shepstone	14.52	16.66	8.69	3.27	43.14	4
Umkoman River	Midway—Richmond	9.39	19.22	8.70	1.98	39.29	5	Outfall—No record	.....	.....	.....	.....	.....	....
Umgeni River	Source—Howick	7.23	14.28	8.16	0.96	30.63	4	Midway—Maritzburg	7.90	17.90	8.66	1.21	35.68	(?)
Umvoti River	Source—Greytown	9.93	15.51	6.19	1.20	32.83	5	Outfall—Stanger	11.58	13.12	9.21	3.58	37.49	5
Tugela River	Source—No record	.....	.....	.....	.....	.....	....	Midway—Ladysmith	5.57	14.15	13.30	0.75	33.77	3
Buffalo River	Source—Newcastle	5.39	17.89	6.69	0.42	30.39	3	Midway—No record	.....	.....	.....	.....	.....	....

The writer, however, will give one instance which has quite convinced him that farming without irrigation, under the erratic rainfall conditions of South Africa, is no pastime. The average summer rainfall for Maritzburg is 17.90 ins., but during 1901-02 it was 10.62 ins., and during the season of 1902-03 it has been only 6.29 ins., with the result that no crop could be grown without artificial watering, and everything sown under rainfall conditions was a failure It is unfortunate that no hydraulic engineer has yet had the opportunity to discuss the detailed rainfall records of South Africa from his own point of view, for there is much to be learned which the ordinary reports do not deal with, such as seasonal rainfall, intensity of precipitation, droughts, variableness of the rainfall, etc., etc.

The writer, however, hopes that, as regards seasonal rainfall, which is so important in considering irrigation, he has helped to fill the gap, as far as the records at his disposal allowed.

TABLE No. 4.—RAINFALL AT MARITZBURG, NATAL, FOR 6 YEARS, 1895–1900; AND AT THE WRITER'S FARM, 2 MILES FROM THE CITY, DURING PART OF THE PERIOD, 1902–03.

Season.	1895	1896	1897	1898	1899	1900	Average.	1902	1903
Spring.....	5.64	8.54	7.00	10.28	9.86	6.11	7.91	3.64	.....
Summer.....	30.98	17.06	13.28	19.37	15.31	11.41	17.90	10.62	6.29
Autumn.....	8.73	7.80	9.95	13.43	5.63	6.42	8.66	7.21	.....
Winter.....	0.62	2.42	1.43	0.56	0.98	1.25	1.21	2.89	.....

The writer would advocate strongly the use of seasonal, instead of monthly, or annual, rainfall records in dealing with irrigation problems, as they show in a much clearer manner what, if any, artificial watering is required for any particular crop.

In the writer's report on colonial irrigation,* forms were provided which included the seasonal rainfall among other details to be recorded.

THE WATER SUPPLY.

The writer has compiled in Tables Nos. 5, 6 and 7 lists of the principal rivers of South Africa, together with facts which are likely to be useful to the hydraulic engineer.

* Blue Book, G 76, of 1899.

TABLE No. 5.—Rivers of Cape Colony.

Hydrographic District.	Name of river.	Source.	Outfall.	Length in miles.	Rainfall, in Inches.	
					Source.	Midway.
1..	Buffels.....	Langeberg Mts.....	Atlantic Ocean..	170	5.74	9.74
2..	Breede.....	Ceres.....	Indian Ocean....	140	41.65	13.03
2 .	Great Berg..	Paarl.....	Atlantic Ocean..	100	25.58	22.36
2..	Olifants.....	Bonteberg Mts.....	Atlantic Ocean..	215	6.43	9.41
3..	Hartebeeste.	Nieuwveld Mts.....	Orange River...	370	10.01	7.11
4..	Gouritz.....	Nieuwveld Mts.....	Indian Ocean....	200	9.74	8.40
5..	Sundays.....	Sneeuwberg Mts.....	Indian Ocean....	200	18.76	13.07
5..	Gantoos.....	South of Victoria West	Indian Ocean....	260	11.76	11.04
6..	Brak.....	Near Victoria West...	Orange River...	160	12.05	12.05
7..	Kraal.....	Stormberg Mts.....	Orange River...	115	27.70	28.31
7..	Sea Cow.....	Sneeuwberg Mts.....	Orange River...	110	No record.	14.45
8..	Great Salt...	Zuurrberg Mts.....	Indian Ocean....	265	20.28	18.21
9..	Great Kei...	Stormberg Mts.....	Indian Ocean....	160	23.79	27.66
10..	Umzimvubu	Drakensberg Mts.....	Indian Ocean....	150	35.21	34.11
11..	Malopo.....	Kalahari Desert.....	Orange River...	380	No	record.
12..	Groen Water	Mount Huxley.....	Orange River...	115	No record.	16.59
12..	Harts.....	Transvaal.....	Vaal River.....	140	No record.	25.50

In addition, the Orange and Vaal Rivers form boundaries between the Cape, Orange River and Transvaal Colonies. The former is approximately 1 100, and the latter 600 miles, in length. Mention should be made here of the great mountain of the Drakensberg Range, "Mont aux Sources," 11 000 ft. in height, from the base of which four important rivers take their source, viz., the Wilge River flowing north, the Tugela River flowing east, the Orange River flowing south, and the Caledon River flowing west.

The Vaal River also rises in the Great Drakensberg Range, but further north.

TABLE No. 6.—Rivers of Orange River Colony.

Name of River.	Source.	Outfall.	Length, in miles.	Rainfall, in Inches.		
				Source.	Midway.	Outfall.
Caledon.....	Mont aux Sources ..	Orange River...	235	.....	34.41	21.80
Riet.....	Beyers Bergen.....	Vaal River.....	190	.....	.....	19.76
Modder.....	Beyers Bergen.....	Riet River.....	170	.....	25.39	19.76
Zand.....	Klokolani.....	Vaal River.....	180	.....	.....	23.35
Valsch.....	Witte Bergen.....	Vaal River.....	155	.....	27.17	.....
Rhenoster.....	Elands Kop.....	Vaal River.	100	No record.		
Wilge.....	Mont aux Sources ..	Vaal River.....	150	29.14	.....	.....
Klip.....	Drakensberg Mts...	Vaal River.....	80	30.39	.....	.....

Rivers of Transvaal Colony.—The Transvaal has not been as well mapped as the other colonies, particularly the northern portion, which contains the principal streams. Generally speaking, a line drawn east and west through Johannesburg would represent, approximately, the divide between the Vaal and Limpopo Rivers, and south of that line the streams, comparatively speaking, are insignificant.

TABLE No. 7.—RIVERS OF NATAL COLONY.

Name of river.	Source.	Outfall.	Length, in miles.	Rainfall, in Inches.		
				Source.	Midway.	Outfall.
Umzimkulu	Drakensberg Mts.	Indian Ocean	110	.....	28.40	43.14
Umkoman	Drakensberg Mts.	Indian Ocean	100	.....	39.29	.....
Umgeni	Drakensberg Mts.	Indian Ocean	85	30.63	35.68	42.46
Umvoti	Drakensberg Mts.	Indian Ocean	65	32.83	.....	37.49
Tugela	Mont aux Sources	Indian Ocean	210	.....	33.77	.....
Buffalo	Drakensberg Mts.	Tugela River	130	30.39	.....	.....

Snow falls more or less on the principal mountain ranges every winter, particularly the Drakensberg, Stormsberg, Sneeuwberg and Langeberg.

The writer has estimated* that approximately 5% of the rainfall, as flowing waters, plus, possibly, 1% as ground-waters, might be available in the Cape Colony for irrigation; the mean annual rainfall varying from 6 to 33 ins. for the various hydrographic districts.

Allowing 2 acre-feet in the fields, as the duty of water, the supply worked out as sufficient for 4% of the total area of the Colony for which statistics were available (viz., Districts 1 to 10), say 5 000 000 acres.

In the light of present knowledge it is difficult to say whether this was under or over estimating the case.

The writer, however, has since seen an estimate† made for the arid districts of the United States in which the supply there is stated as sufficient for 74 000 000 acres, the total land surface being 892 000 000 acres; or, practically, for 8% of the area of the arid districts in the United States, as against 4% for ten out of the twelve hydrographic districts of Cape Colony.

* "Special Report on Colonial Irrigation, and Hydrographic Survey, with Statistics." Cape of Good Hope Blue Book, G 76, 1899.

† "Irrigation in the United States," by Frederick Haynes Newell, Chief Hydrographer, U. S. G. S., 1902.

Owing to the scarcity of rainfall records, it was not found possible to estimate for Districts 11 and 12, and therefore they were excluded.

The writer understands from Mr. Newell's book, however, that in the United States at the present time the total area actually irrigated does not equal 1% of the land surface. Very few flow measurements have been made in South Africa, therefore the following records may be found to be of interest:

Hydrographic District No. 4, Cape Colony.

Principal river basin	Gouritz River.
Branch stream	Nels River.
Catchment area, in square miles	68
Extreme length, in miles	11
Mean width, in miles	6.19
Summer rainfall, in miles (one season, '97–98)	3.07
Period of measurement of flow, Nov. 21st, '97, to Feb. 21st, '98.	
Discharge in millions of cubic feet	55.8
" " acre-feet	1 280
Estimated maximum flood, in cubic feet per second.	5 200
Observed " " " " "	1 378
Observed maximum flood, in cubic feet per second per square mile	20.25
Observed minimum flow, in cubic feet per second.	0.077
Coefficient of discharge, for summer	0.115

The coefficient of discharge is referred to the rainfall at the lower end of the catchment. If referred to the gauge on the mountains, it would be only 0.056.

The river was cross-sectioned very carefully, and velocities were measured by floats at various stages of the stream. The heights were measured at a gauge post at irregular intervals, but the results are believed to be fairly accurate.

Hydrographic District No. 8, Cape Colony.

Principal river basin	Great Salt River.
Branch stream	Theebus River.
Catchment area, in square miles	78.84
Extreme length, in miles	11.62
Mean width, in miles	6.79

Rainfall, in inches, for one year, Oct., '96, to Sept., '97	13.75
Period of measurement of flow, Oct., '96, to Sept., '97.	1 year.
Discharge, in millions of cubic feet	141⅐
" " acre-feet	3 240
Observed maximum flood, in cubic feet per second.	379
" " " in cubic feet per second per square mile	4.8
Observed minimum flow, in cubic feet per second.	0.23
Coefficient of discharge, for the year	0.055
" " " " spring	0.016
" " " " summer	0.065
" " " " autumn	0.050
" " " " winter	0.076

The coefficients of discharge are referred to the mean of nine to fifteen rain gauges located over the catchment. The flow was measured very carefully over a 20-ft. rectangular notch, and, in addition, a 12-in., V-notch was used for small discharges.

Hydrographic District No. 8, Cape Colony.

Principal river basin	Great Salt River
Branch streams	Theebus and Rhenoster Rivers
Catchment area, in square miles	145.58
Extreme length, in miles	19.5
Mean width, in miles	7.47
Rainfall, in inches, for 1898	19.36
Period of measurement of flow, Jan. 1st to Dec. 31st, '98	1 year.
Discharge, in millions of cubic feet	702
" in acre-feet	16 119
Observed maximum flood, in cubic feet per second.	11 150
" " " in cubic feet per second per square mile	76.6
Observed minimum flow, in cubic feet per second.	0.42
Coefficient of discharge, for the year	0.107
" " " " spring	0.065
" " " " summer	0.147
" " " " autumn	0.028
" " " " winter	0.257

The coefficients of discharge are referred to the mean of twenty-two to twenty-three rain gauges located over the catchment. The flow was measured carefully over one 12-in. V-notch, two 20-ft. rectangular notches, and, for extreme floods, a channel 150 ft. in length. During January, 1898, the average rainfall over the catchment was 6.45 ins., while the previous average in the village for 9 years was only 2.62 ins. On December 6th, 1898, 3.07 ins. fell, the average for the month of December for 20 years being 1.96 ins.

The measurements for District No. 8 were not made by the writer. They are believed to be thoroughly reliable.

The Crops.

The principal ordinary crops grown in South Africa are as follows: Maize, Kaffir corn (*Sorghum vulgare*), oats, barley, potatoes, pumpkins, beans and lucerne.

These are the standard crops, grown more or less by almost every farmer, while wheat and turnips are only grown in certain districts. Excluding the comparatively small portion of the Cape Colony which is subject to good winter rains, the periods of sowing and the number of months taken to mature crops are generally as shown in Table No. 8.

TABLE No. 8.—Period of Sowing Crops, Etc.

Crop.	Period of sowing.	Time taken to mature.
Maize	October to January	3 to 4 months.
Kaffir corn	"	5 to 6 "
Oats	April to June	6 "
Barley	"	6 "
Potatoes	August to February	3 "
Pumpkins	November to January	3 "
Beans	December or January	3 "
Lucerne	Spring or autumn	(Perennial.)

As a rule, oats, barley and lucerne are grown under irrigation, and the others generally as dry crops, but the maize and Kaffir corn would benefit greatly by being irrigated also. That this is not done is due to the fact that they are grown on a much larger scale than the other crops, and usually on lands which are not capable of being watered from the small irrigation systems of most farmers. Oats and barley

can be grown during the summer months, but as they almost invariably rust at that time, the winter crop is preferred.

The early and late crops of potatoes are the most valuable, the first to catch the market at a time of the year when they are very scarce throughout South Africa, and the last to keep as long as possible through the winter. Maize and Kaffir corn are generally grown for their grain and the stalks are given to the cattle afterward. Oats and barley are grown for forage; the former is generally sold in pressed bales as oat hay. The latter is usually sold green after it has come into head. Lucerne is sometimes used green for fodder, and sometimes made into hay and baled.

As a rule, the yield in South Africa is poor. The following are considered fairly good crops under favorable rainfall conditions:

Maize (corn) ½ ton per acre, say 16 bushels;
Oats (forage) 1 ton per acre;
Potatoes, 3 tons per acre, say 127 bushels.

The usual prices obtained for good samples are as follows, depending on the supply:

Maize (corn)	per 100 lbs.	.....	6s.	to	11s.
Oats (forage)	"	.....	6s. 6d.	to	10s. 6d.
Potatoes	"	.....	7s.	to	14s.
Lucerne (hay)	"	.....	8s. 6d.	to	10s. 6d.

Maize, Kaffir corn, pumpkins, and potatoes will not stand any frost, while oats, barley, and lucerne are not injured thereby. Frosts may occur anytime between April and August, and occasionally in September and October. They are sometimes very severe, depending on the altitude, and often ruin the fruit crops in high places, like the Stormberg District in the Cape Colony.

Apple and pear trees bloom in August and September, and the fruit is ripe in December to March. Citrus fruits, such as oranges and lemons, are ripe in June to September, grapes in January to March, and peaches and Japanese plums in January and February. Grapes are grown on a very large scale in vineyards, for making wine and brandy, in the district subject to winter rains (Western Province of Cape Colony), and are usually irrigated.

Elsewhere, with summer rains, which spoil the quality, they are only grown on a small scale in private gardens.

With regard to the water supply required to produce a crop, the following may be looked on as a minimum, but for full development double the quantity is not too much in the case of cereals and lucerne:

Maize and Kaffir corn	18 ins.
Oats and barley (winter crop)	9 "
Potatoes	15 "
Lucerne	24 "
Apple trees	15 "
Grape vines	18 "

The writer would strongly advocate all crops being sown in drills with wide intervals, instead of either broadcast or in drills with narrow intervals, as generally practised. He has experimented a good deal in this direction, and believes the following distances will usually result in a yield quite up to the average, while the advantages, in the way of enabling water to be easily applied, are very great.

Maize for Corn.—Six feet between the drills and plants 3 ft. apart in the drill.

Maize for Fodder.—Three feet between the drills, and continuously in the drill.

Oats and Barley.—Three feet apart between the drills, and continuously in the drill, with the usual allowance of seed per acre.

Lucerne.—Two feet apart between the drills, and continuously in the drill.

In the latter case the writer commenced with 1½-ft. intervals, but, finding that the outside rows always came up about 50% higher than the others, he increased the distance to 2 ft.

The South African Farmer.

The South African farmer carries on his art under difficulties which would appal many an English farmer, notwithstanding the latter's troubles in the way of low prices, bad weather, and occasional shortage of labor.

The weather and labor troubles are serious enough in South Africa, probably worse than in England, but, in addition, there are many other things, such as insects and fungus pests, very dangerous cattle diseases, and, in the majority of cases, want of transport facilities, and farms far too large for anyone with an ordinary amount

of capital to work properly. Implements, good seed, and manure are also high in price, and at times unobtainable.

When the war broke out, in the beginning of October, 1899, that is 3½ years ago, it practically put a stop to all professional work for the Civil Engineer, and that state of affairs has continued to the present day. Under these circumstances the writer has learned his lesson in South African farming in that greatest of all schools "Practical Experience." That experience was undertaken with two objects in view, the first being to try and reduce the cost of living in the most expensive country in the world during a very trying time, and the second to gain some knowledge of the needs of the farmer as regards irrigation. The writer's opportunities, like his water supply, have been limited, but he has learned much, and he hopes a few of his gleanings from his farm of 40 acres in Natal, may be of interest to others.

The majority of insect pests are worse in seasons of drought, when the plants are least able to withstand their ravages, and it is probable that plentiful irrigation would, in most cases, locusts excepted, result in a crop in spite of them.

The following are the writer's notes as to the water supply necessary to give a crop, but, of course, the question is complicated by that unknown factor, the quantity of moisture in the ground, at the time of sowing, of which the plants can avail themselves.

Maize.—Sown on sloping ground in rows 3 ft. apart, on November 4th, 1902. Each row 2 Gunter's chains in length. Rather dry, red soil. Rainfall, as follows, from time of sowing to time of full maturity: November, 1.38 ins.; December, 3.27 ins.; January, 1.06 ins.; and February, 1.85 ins.; total, 7.56 ins. Irrigated on November 17th, December 3d and January 7th, each time with 40 cu. ft. per row; equivalent to 1¼ ins. of rainfall each time.

Notwithstanding this treatment, and the rainfall, they wilted considerably; some of the leaves died off, and they did not develop as they should. Irrigation was then commenced at the rate of 80 cu. ft. per row, equivalent to 2½ ins. of rainfall. Two of these irrigations were given, one toward the end of January and the other early in February, and the effect was very marked in increasing the growth and the color of the leaves.

Including the rainfall, the quantity of water was 16½ ins., which is

rather under the average summer rainfall of Maritzburg, with which tolerably fair maize crops are grown without irrigation.

The crop in question was fair, the average height being 5½ ft., but would have been better with earlier irrigation.

Another crop, under rainfall conditions alone (6 ins.), but sown later, has only attained an average height of 2½ ft., and is a failure.

Last year a poor crop was obtained on flat ground, and rather moist black soil, without irrigation, the total rainfall being about 14 ins. The writer is of the opinion that maize will benefit, and only obtain full development with at least 36 ins., including rainfall.

Oats.—During the winter season, 1902, the writer's forage crop was decidedly good, and was grown entirely under rainfall conditions, but in the previous winter no crop was taken off the ground. Height, 2½ to 4 ft. Period of sowing, April 2d to June 4th. Period of reaping, October 6th to December 11th. Weight of crop per acre (straw and grain), about 1 ton. Rainfall for average period, 8¾ ins.

In this case there would be more moisture in the ground at the time of sowing than in the case of maize, as it was at the end of the monsoon, instead of the beginning, and besides the dews are heavy during winter and the evaporation less.

Potatoes.—During the season, 1901–02, the writer had a good crop of potatoes, for South Africa. These were not irrigated, as the rainfall was ample. They were planted on December 16th and were ripe at the end of March.

The rainfall during this period was as follows: December, 2.71 ins.; January, 3.79 ins.; February, 3.47 ins.; March, 4.99 ins.; total, 14.96 ins. The vines attained full development and flowered profusely, and some of the tubers were very large. The seed was Sutton's (imported) Early Rose. Yield, 3 tons per acre.

Lucerne.—The lucerne plots are 5 Gunter's chains in length by 22 ft., and in some cases 33 ft. wide, and are being watered by eight-arm sprinklers, working under a head of about 23 ft., at the rate of 1¼ ins. every 20 days, plus rainfall. It is too early yet to speak of the results with certainty, but there is a fair growth.

The writer, however, from his experience in the Cape Colony, believes that while 24 ins. per annum will produce a fair crop, 48 ins. are required for a good one, and the rainfall should be supplemented accordingly.

Apple Trees.—During the season, 1901–02, twenty apple trees produced 1 500 lbs. of fruit. The trees blossomed in September. The first apples were picked on December 16th, and the last on February 5th.

From the time of blossoming to the end of the fruit season the rainfall was 11.7 ins., and during this period each tree got three irrigations, each of 30 cu. ft.; a total of 90 cu. ft., which corresponds to, say, 2.3 ins. of rainfall when the trees are set about 22 x 22 ft. apart. The total quantity of water was therefore 14 ins. This was a good crop for South Africa.

During the season of 1902–03, the same number of apple trees only produced 900 lbs. of fruit. The trees blossomed in September. The first apples were picked on December 18th, and the last on February 18th. From the time of blossoming to the end of the fruit season the rainfall was 7.9 ins., and during this period the total irrigation, divided among all the trees, was 5 300 cu. ft., corresponding to 6.6 ins. The total quantity of water was therefore 14.5 ins. In this case, owing to the drought, there would have been no crop at all but for irrigation, as a tree higher up which could not be irrigated produced nothing although it blossomed as well as the others. Owing to the scarcity, the apples sold at the Christmas market realized 4 d. per pound.

Lifting Water for Irrigation.—All the writer's irrigation has been done with ground water. On the western boundary of the farm there is a sluit (stream) with a dry bed, except immediately after thunderstorms; and at one place on the bank there was a small spring which kept this particular spot moist. On this site the writer sank a well, lining it continuously with galvanized corrugated-iron sheeting, from 6 ft. above the ground surface to the bottom. The sheets were bent in the ordinary way in rolls, each to a semi-circle, as used for making tanks; but, instead of soldering them together, the writer fastened them with bolts and nuts, as it was not necessary or desirable that the lining should be watertight. The total depth of the lining is 30 ft., the diameter at the top 8 ft. and at the bottom 6 ft. The lining was bolted up in sections, generally 4 to 8 ft. in height, and was passed down as sinking proceeded, the diameter, of course, diminishing continually from top to bottom. The top portion, 6 ft. above the ground level, was designed to keep out floods and cattle. The well was also roofed over to keep out leaves and branches from the neighboring

trees. A small door was placed on one side for inspection, and a trap door in the flat roof to allow of additional sinking if required. A ladder was fixed inside to give access to the suction pipe and foot-valve.

The writer can recommend this method, in a country where brick or masonry lining is very expensive, until the water supply has been proved to be worthy of further expenditure, and afterward it would be easy to fix a mould and provide a thin concrete lining. An engine-house, 16 × 9 ft., of old corrugated sheets, has been erected just outside the well, in which the lifting machinery is placed, consisting of a Gardner oil engine, 1½ B. H.-P., and a Tangye double-acting horizontal pump, 4 ins. in diameter and with a 6-in. stroke. The suction pipe is 2 ins. in diameter, with one bend, and the average lift is 43 ft. to a large corrugated-iron tank through 850 ft. of galvanized wrought-iron piping, also 2 ins. in diameter, with eight bends.

The main passes through lucerne beds, which are at the same level as the engine and pump, and is provided with crosses every 33 ft. having 1½-in. outlets closed by plugs, so that hose can be connected for attachment to sprinklers. The sprinklers usually work under the tank head, but occasionally they are worked under the pumping head when the engine is in operation. In the former case each sprinkler throws about 175 to 200 galls. an hour, but in the latter case the discharge is more than doubled, as they run very fast under the pumping head.

The pump throws 20 to 30 galls. a minute, depending on the pulley used, but could be run faster if necessary.

The engine, which works at 320 revolutions a minute, is also used to drive a corn mill which is placed alongside the pump, for grinding maize, wheat, beans, peas, etc., coarse or fine, as required for cattle and poultry feeding purposes, or for household use. With engine, pump, and piping new and in good order, the cost of lifting 1 000 galls. of water 43 ft. high through the main referred to is, for fuel alone, 1½ pence, that is for ¾ pint of "Homelight" kerosene oil at 11 shillings per case of 8⅓ Imperial gallons. This amounts to £1 14 shillings per acre-foot. In many cases 6 ins. of water plus the rainfall would make a good crop, and the writer thinks it would pay to lift water in this way, even with oil costing 20 shillings a case, which would include most districts in the Orange River and Transvaal Colonies which are served by railways.

A special and very careful measurement was made of the oil used, which includes both cylinder and lamp, and the water pumped was measured in the tank previously referred to.

Labor and Materials.

The labor question is a serious one in South Africa. The Kaffir is lazy, finds living very easy, and will not work continuously. The general public object to the importation of Indians on an extensive scale because they eventually enter into competition with small white traders, and occasionally with large ones, and, worst of all, the white man does not labor partly because he thinks it undignified while the Kaffir is here to do it for him, and partly because, as a rule, he is not offered a proper living wage.

If white labor is to develop the country, the cost of living, which is abnormally and improperly high, must be diminished. As things are, the mines and the various Colonial Governments monopolize all the colored labor for their works, and want more, and the unfortunate farmer comes in a bad third. With regard to materials, imported Portland cement is generally used for masonry or concrete on public works, and the cost, in bond at Cape Town or Durban, for barrels of 400 lbs. gross, being about 11 to 13 shillings for good brands. The duty per 100 lbs. is 6 pence, say 13 to 15 shillings per barrel at the coast, duty free, and the cost of carriage by rail up country about 5 shillings per barrel per 100 miles.

This high charge and the long distances involved make the use of cement up country almost prohibitory, as far as economical works are concerned. The writer, in his "Report on Colonial Irrigation," advocated a thorough investigation into the nature and composition of the various limestones obtainable locally, with the view of ascertaining how far these might be substituted for cement in the construction of hydraulic works, but, as far as he knows, this has not been done yet in any of the colonies.

Stone fit for concrete can generally be obtained, but good clay for puddle is scarce in many parts of the country. Timber is dear, viz., from 4 to 7 shillings per cubic foot at the coast, while the carriage by rail is fully 6 pence per cubic foot per 100 miles.

The Law.

The Common Law of South Africa pertaining to water rights is the Roman Dutch Law. This law divides streams into two main divi-

sions, viz., public streams and private streams, and the former are defined as perennial streams.

Public streams are common to all for the purpose of supporting life, and therefore the rights of riparian proprietors are always limited by the natural rights of the public, as far as the latter are capable of being exercised. The Roman Dutch Law is sufficiently elastic to adapt itself to the special characteristics of the country. For instance, it has already been accepted as an axiom, in the Courts of the Cape Colony, that a river may become dry in the heat of summer without forfeiting its character as a perennial stream. That is to say, a distinction is drawn between streams which generally flow, and only occasionally become dry, and streams which are generally dry and only flow after rain.

It is therefore probable that the law is capable of adapting itself to practically all the needs of this country, as regards irrigation, in the same way as the Common Law in the United States has adapted itself already, in a great measure, to the needs of that country.

It does not follow, however, that the law is perfect as it stands; far from it; and some alterations are certainly required. The most urgent requirement is a right of passage of water act (carrying with it, of course, a right to expropriate land on payment of reasonable compensation), which can be utilized in the case of beneficent works, and, needless to say, governments strong enough to carry out its provisions, because the Cape Act, thus far, has been a dead letter.

If there is one thing which the Roman Dutch Law recognizes, it is that actual beneficent use must be proved before any right to water can be obtained, and this is a most important matter.

The Future Possibilities of Irrigation.

There is still ample room in South Africa for individual private enterprise to use ground waters, pump from perennial rivers, and in some cases make reservoirs on large farms having private streams.

There is also room for enterprise on a large scale to lead water from streams too deep beneath the surface of the country to be dealt with by the ordinary farmer's furrow; but, in such cases, weirs, and other engineering works of magnitude, are required; however, until the law is amended, these works could not easily be undertaken by private enterprise.

It is possible, also, that a few large storage works might be carried out in the same way, but the writer is of opinion that, as a rule, it would not pay private enterprise to undertake them, as the cost of construction, under present circumstances, is likely to be very high.

It has been recommended by Mr. W. Willcocks, of the Daira Sania Company, of Cairo, that all public streams in the Transvaal and Orange River Colonies should be proclaimed as state property, which, as the writer understands it, would result in all irrigation works being carried out by the Government for the good of the general public.

Thus far, this proclamation has not been made, but it is quite certain, on the other hand, that if irrigation is left wholly to private enterprise, the Government will be left, eventually, as in the United States, to deal with the storage problem.

Much can be said on both sides, but it must be remembered that in South Africa the Governments do not possess Crown Lands in the same wholesale way as America possesses Public Lands in the arid Western States.

In some parts of the Transvaal, particularly, there are ground-waters, on a very extensive scale, from which considerable development may be expected, and both in the Transvaal and Orange River Colonies most of the rivers flow for long distances with very little fall through the comparatively flat country of the central districts, and rather deep beneath the surface.

In his evidence before the Imperial Land Settlement Commission, at Cape Town in 1900, the writer advocated pumping schemes on a large scale as suitable for the country. It will therefore not be out of place to compare the existing conditions with those in Egypt, where pumping is largely resorted to and is successful.

In Egypt.—

1. English coal is imported and used successfully, the cost being about 45 shillings per ton;
2. Natives have charge of the machinery;
3. The lift is generally low;
4. The average winter temperature of Lower Egypt is 57° Fahr., and of Upper Egypt 60° Fahr.;
5. The mean annual rainfall of Lower Egypt is about 4½ ins., and Upper Egypt may be described as rainless;

6. The ruling price of wheat is 2s. 6d. to 3s. per bushel; maize, 2s. 3d. per bushel; beans, 2s. 9d. per bushel, and other produce on a similar scale;
7. The yield of maize varies from 35 to 50 bushels per acre (irrigated).

In South Africa.—

1. Colonial coal is available;
2. The Kaffir is far from being mentally inferior to the Egyptian;
3. The lift, generally, would be high;
4. The average winter temperature of Johannesburg is about 52° Fahr., which may be considered typical of a large portion of South Africa away from the coast, and at a considerable elevation;
5. The mean annual rainfall is much heavier than in Lower Egypt, but is erratic, as in all arid and semi-arid countries;
6. The price of wheat per bushel varies from 6 to 7 shillings at the coast to 7 to 9 shillings up country on the line of railway, maize 4 to 6 shillings per bushel, and other produce on a similar scale;
7. The yield of maize is about 16 bushels, without irrigation, but in certain districts and in favorable years it may be doubled.

In South Africa, as compared with Egypt, the disadvantages are temperature and lift, and the advantages, local coal, heavier rainfall, and higher prices for produce.

Three crops in the year can be obtained in Egypt, but, under the temperature conditions of South Africa, as a rule, only two, although in places like Maritzburg, Natal, three crops are also possible.

Coal is found over extensive areas in the Cape, the Transvaal and Natal, and in some cases the quality is very good. The price to the general public is unnaturally high, viz., at the Cape about 22 shillings per short ton on trucks at the pit, although the Government gets it for the railways at about 15 shillings; but, doubtless, this will be remedied when things settle down. The cost of carriage varies from 2 to 4 shillings per ton per 100 miles, depending on the direction.

The writer is of the opinion that it would be advantageous to use windmills on a large scale in some parts of the country to lift water for irrigation; and Hydrographic District No. 12, in the Cape Colony, is a particularly suitable area. The following is taken from the records of the wind force at Kimberley, in that district, during 1899:

	Spring.	Summer.	Autumn.	Winter.
Number of days during which the wind force, during the whole 24 hours, exceeded 4 miles per hour	80	83	66	65
Number of days during which the wind force, during the whole 24 hours, exceeded 8 miles per hour	21	23	8	13

Ground water is generally plentiful in this district at a reasonable depth from the surface. Mr. Willcocks has estimated that in one-fifth of the Cape Colony, one-half of the Orange River Colony, and two-thirds of the Transvaal, maize, potatoes, roots, generally, and pumpkins can be grown with the aid of the rainfall, but the writer is somewhat inclined to think that these areas have been over-estimated, and the erratic nature of the precipitation and the farmer's difficulties under-estimated.

In some ways South Africa is not unlike the United States, for instance, the dividing line (20 ins. of rainfall) between the arid and sub-humid districts, may be roughly said to lie between Vryburg and Port Elizabeth (24th to 26th degree of longitude) cutting the country in half, while in the United States the same division also occurs about midway (97th to 100th degree of longitude), and in both cases the arid portion lies to the westward.

The principal difference lies in the fact that South Africa is more in need of irrigation than the United States, inasmuch as the western half is more arid and the eastern half less humid, making irrigation a practical necessity for successful agriculture over almost the whole of the country, with the exception of a narrow fringe along the coasts.

The following comparison with Spain, which is not on the whole a very thickly populated country, will give some idea of the area available for settlers.

TABLE No. 9.

Country.	Area, in square miles.	Population, including natives.	Date.
Spain	191 367	17 500 000	1890.
Cape Colony	277 151	1 500 000	1891
Orange River Colony	41 500	200 000	1890
Transvaal	119 128	750 000	1890
Natal	29 434	900 000	1898
South Africa	467 213	3 350 000	.....

The following distances are measured on the railways:

Cape Town to Bulawayo	1 322 miles.
East London to Bloemfontein	400 "
Durban to Johannesburg	483 "
Cape Town to Durban	1 463 "

In concluding, the writer hopes that his agricultural remarks and statistics may not be considered out of place, if somewhat unusual; for, if the hydraulic engineer is to cater for the irrigation needs of the farmer he should know something of the latter's crops, their seasons, requirements and value, and the difficulties which are encountered in growing them.

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PAPERS AND DISCUSSIONS.

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SOME RAILWAY CONSTRUCTION IN OKLAHOMA.

By A. G. Allan, Assoc. M. Am. Soc. C. E.

To be Presented October 21st, 1903.

During the past eighteen months the writer has been in charge of about 60 miles of new railway construction, on which were built a number of different structures, some of them not usual in new railway work in the West, and, thinking that perhaps it might enable someone similarly situated to make approximate estimates of cost, or help in the design of masonry to be built in advance of the track, he begs to submit this paper.

It would be proper to state that there is no claim for originality in the plans, many of them being merely modifications of the standard plans of the road, the others having been used elsewhere by other members of the engineering profession.

All the construction described is on a portion of a line being built by the Atchison, Topeka and Santa Fé Railway from Newkirk, Oklahoma (a point 14 miles south of the Kansas State line), to Pauls Valley, Indian Territory.

As it is intended to use the new line for heavy freight traffic, the maximum gradient adopted was 0.6%, compensated for curvature at the rate of 0.05% per degree.

The sharpest curve allowed was of 4°, all curves of 3° and more

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

being spiralled by the six-chord spiral, a modification of a parabolic curve originated by Mr. J. R. Stephens, Engineer in Charge of Construction, the grading being cross-sectioned and built on the offsetted curves.

Degree of main curve.	Length of terminal curve, in feet.	Degree of terminal curve.	Terminal angle.	Offset, in feet.
3°	100	1° 30′	1° 30′	0.65
4°	120	2° 00′	2° 24′	1.25

For intermediate curves, intermediate values were taken.

The length of the terminal curve is exactly divisible by four, to avoid fractions in the chord lengths.

The terminal curve has a radius of twice the length of the main curve; the spiral is half as long again as the terminal curve, one-sixth running back on the tangent, four-sixths consuming the terminal curve, the remainder being on the main curve.

The line leaving Newkirk runs across drainage for the first 8 miles, so that some heavy grading was necessary, and a number of openings were required; for the rest of the way, to the first crossing of the Arkansas River, the location is along drainage lines presenting no unusual features.

In this first section the entire country consists of a thin soil overlying solid limestone, which can be drilled and quarried easily to any dimension, and which cuts perfectly. This stone hardens on exposure to the air, and is not shattered by frost.

The original plans called for wood-box culverts, but, on account of stone being obtainable and the line being built for heavy traffic, the Chief Engineer, James Dun, M. Am. Soc. C. E., changed to arches all the pile trestles which had sufficient headroom, and the wood boxes to masonry culverts. A contract for the masonry was let to Mr. L. W. Lewis, of Emporia, Kans., at the following prices per cubic yard:

Bridge masonry	$5.75
Rubble masonry	3.15
Rubble arch masonry	5.25
Paving	3.15
Coping steps and ring stones	6.50
Box culvert rubble masonry	3.15



FIG. 1.—TYPICAL 10 x 6½-FOOT ARCH CULVERT.

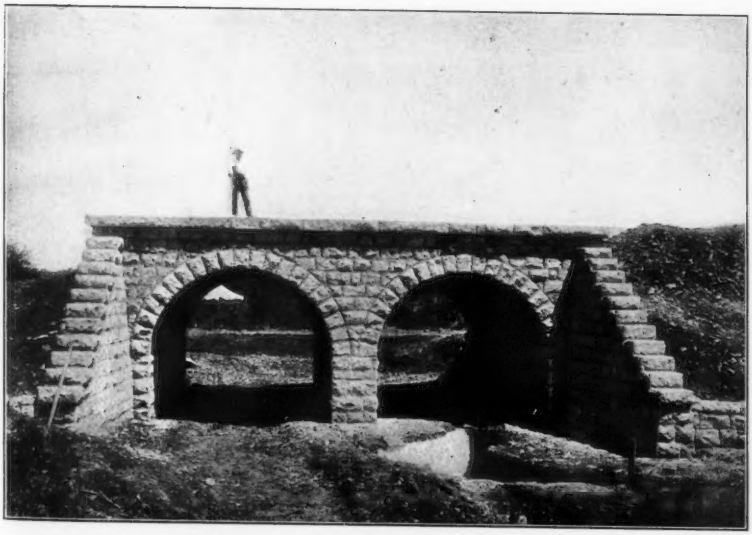


FIG. 2.—DOUBLE 14 x 5½-FOOT ARCH CULVERT.

Box culvert rubble dry	$2.50
Covering stone for box culverts	5.25
Concrete in foundations	3.00
Earth excavation above water	0.35
Loose rock excavation above water	0.50
Solid rock excavation above water	1.00

All excavation below water at cost plus 10% for use of tools and supervision.

Overhaul on all stone more than one mile from the site of the work, 40 cents per cubic yard additional to above prices for each mile after the first mile.

The Railway Company furnished the cement, f. o. b. cars, and the contractor furnished the sand, but the company paid the actual cost for hauling the sand and cement from the cars to the site of the work. The Railway Company furnished transportation for men, teams, tools and material to and from the work.

The excavations for the foundations were commenced during the first week in May, and the last masonry was finished in October, all sand being teamed from 2 to 15 miles, at a cost varying from $1.40 to $3.25 per cubic yard.

The cement used was manufactured by the Iola Portland Cement Company, of Iola, Kansas, and showed the following tensile strengths, from tests at the factory:

NEAT CEMENT (20% WATER).

1 day	204–228	lbs. per square inch.
7 days	630–657	" "
28 "	745–761	" "

CEMENT WITH 3 PARTS SAND (10% WATER).

7 days	206–230	lbs. per square inch.
28 "	310–335	" "

Owing to continuous wet weather and high water in the creeks, it was found almost impossible to separate wet and dry excavation, so that the entire foundation work was done by the contractor on "force account," under the close supervision of the writer and two time-keepers, each detailed to certain jobs.

TABLE No. 1.—Cost of Constructing Arches, Exclusive of Cost of Cement and Sand.

	12 x 4-ft. arch at Station 2920 + 21. See Fig. 1.			10 x 6½-ft. arch at Station 2958 + 06. See Fig. 2.		24 x 10-ft. arch at Station 2672 + 43. See Fig. 3.		Double 14 x 5½-ft. arch at Station 2761 + 33. See Fig. 4.		10 x 5-ft. arch at Station 2425 + 40. See Fig. 5.		8 x 4½-ft. arch at Station 2575 + 80. See Fig. 6.		6 x 5-ft. arch at Station 2594.	
Nature of foundation	Soapstone.			Soapstone.		Gravel and rock.		Solid rock.		Quicksand.		Solid rock.		Solid rock.	
Length of barrel	22.8 ft.			50.03 ft.		28.67 ft.		31.41 ft.		22.64 ft.		49.62 ft.		49.11 ft.	
Length of wings	12.3 "			13.50 "		31.25 "		16.75 "		13.75 "		9.00 "		7.5 "	
Height of headwalls	13.62 "			15.14 "		26.87 "		16.50 "		13.62 "		12.12 "		11.62 "	
	Unit prices.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.
Excavating foundations	.....	*	$317.44	*	$ 242.00	*	†$439.29	.....	$176.87	.....	$157.41	*	$240.89	*	$359.63
Hauling and placing grillage	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	119.90	.....	.....	.....	.....
Concrete	$3.00	81.5	244.50	.....	.....	212.1	636.30	.....	.....	102.4	307.20	.....	.....	.....	.....
Arch rubble	5.25	118.0	619.50	367.8	1 930.95	585.5	3 073.87	453.0	2 378.25	113.5	595.87	285.6	1 499.40	263.3	1 382.32
Coping, steps and rings	6.50	12.6	81.90	12.3	79.95	36.0	234.00	27.2	176.80	12.3	79.95	9.4	61.10	7.8	50.70
Overhaul	0.40	178.2	71.28	91.6	36.64	7.8	3.12	19.4	7.76	25.9	10.36	295.0	118.00	.....	.....
Dry rubble	2.50	7.2	18.00	21.1	52.75	11.3	28.25	6.2	15.50	.....	.....	14.0	35.00	12.3	30.75
Excavating and changing channel	.....	.....	40.43	.....	.....	.....	426.78	.....	.....	*	57.75	*	28.19	*	33.00
Excavating new channel	0.15	.....	.....	523.0	78.45	.....	.....	‡436.0	130.80	.....	.....	.....	.....	.....	.....
Total cost of arch	.....	.....	$1 393.05	.....	$2 420.74	.....	$4 841.61	.....	$2 885.98	.....	$1 328.44	.....	$1 982.58	.....	$1 856.40
Cost per linear foot of barrel	.....	.....	61.10	.....	48.39	.....	168.88	.....	91.88	.....	58.67	.....	39.96	.....	37.80

* Force account.
† A flood in May washed out all excavation, costing $163 to clean up foundations.
‡ At 30 cents per cubic yard.

TABLE No. 2.—Cost of Constructing Box Culverts, Exclusive of Cost of Cement and Sand.

		3 x 3-ft. dry box at Station 2397.		4 x 6-ft. dry box at Station 2404.		4 x 6-ft. rubble box at Station 2622+80. (See Fig. 7.)		2 x 2-ft. dry box at Station 2638+71. (See Fig. 8.)		Double 3 x 3-ft. dry box at Station 2710+08. (See Fig. 9.)	
Nature of foundation		Boulders and gravel.		Boulders and gravel.		Clay.		Soapstone.		Clay.	
Length of box		24.5 ft.		41.06 ft.		28.1 ft.		69.57 ft.		22.0 ft.	
	Unit prices.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.	Quantities, in cubic yards.	Amounts.
Excavating foundations	.....	*	$75.75	*	$150.27	*	$53.62	*	$107.14	*	$32.26
Rubble masonry in cement	3.15	.....	.....	.....	.....	79.5	252.42	.....	.....	9.0†	28.35
Paving	3.15	.....	.....	.....	.....	4.7	14.80	5.4	17.01	6.2	19.53
Concrete	3.00	15.1	45.30	21.4	64.20	.....	.....	.....	.....	.....	.....
Dry rubble	2.50	19.8	49.50	75.0	187.50	.....	.....	49.2	123.00	36.2	90.50
Covering	5.25	6.8	35.70	13.3	69.82	9.1	47.77	16.1	84.52	9.0	47.25
Coping	6.50	1.3	8.45	2.0	13.00	4.1	26.65	1.1	7.15	3.5	22.75
Excavating and changing channel	.....	.....	.....	*	8.85	.....	.....	.....	.....	.....	.....
Excavating channel	.....	.....	.....	.....	.....	.....	.....	*	29.70	.....	.....
Total cost	.....	.....	$214.70	.....	$493.64	.....	$395.26	.....	$368.52	.....	$240.64
Cost per linear foot of box	.....	.....	8.76	.....	12.02	.....	14.07	.....	5.30	.....	10.94

*Force account. †Center wall.

The cost of this excavation varied so much, on account of the different causes, pumping and floods, that it was extremely difficult to get at the exact cost per cubic yard.

An average of five different jobs, including pumping, was 45 cents per cubic yard.

The costs of the masonry, given in Tables Nos. 1 and 2, are for the excavation for the foundations, the excavation required for the channel changes, and the contract price per cubic yard for the masonry contained in each arch or box culvert, no account being taken of the sand and cement used.

The cost of the cement and sand varied with the length of the haul from the river or nearest unloading point, the sand costing from $1.40 to $3.25 per cubic yard, delivered, the larger amount being for sand used on work 15 miles from the river. The average cost of hauling the cement, for six different jobs, was $0.40 per barrel, the average load being 28 sacks, or 7 barrels. This high average was due to the wet weather and, consequently, the bad condition of the roads.

Most of the arches were founded on solid rock, soapstone or other hard material; but one, viz., the 10-ft. arch at Station 2425 + 40, was built on quicksand. In making the foundation excavation for this arch the men sank to their knees. The bottom being too soft for the regular foundation plan, the writer obtained authority from Mr. Stephens to build the masonry on a concrete base on a grillage of old piling, drift-bolted together, to form a solid floor.

This base is 52 ft. long, 20 ft. wide and 2½ ft. thick, weighing approximately 250 tons. It settled about 0.4 ft. before the masonry was commenced. There has been no further movement that could be determined.

The stone for the concrete was broken by hand into pieces small enough to pass through a 3-in. ring, the breaking being done on the site of the work. The stone for the concrete was entirely free from dirt.

The sheeting and ring stones were of the dimensions shown on the drawings, and were laid with ½-in. joints.

The joints were made on the radial lines, and the faces of the sheeting stones were hammered so as to make a close fit on the lagging. No joints closer than 12 ins. were allowed, and each stone was the full depth of the arch. The entire ring was pointed after the centers had been removed.

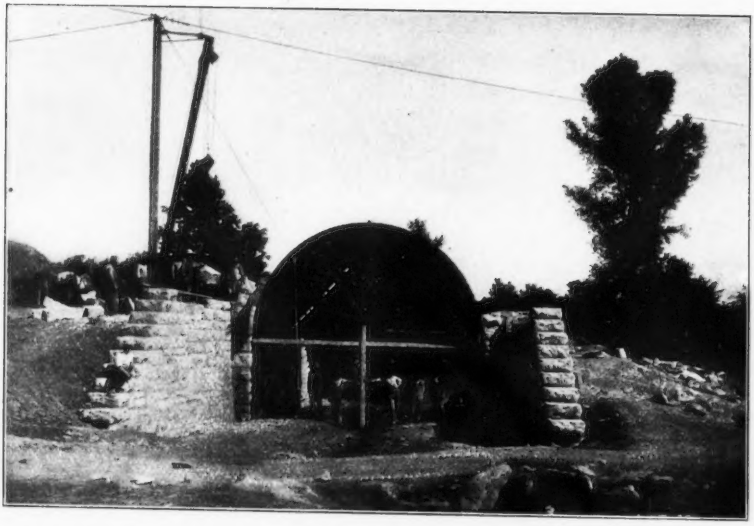


FIG. 1.—24 x 10-FOOT ARCH DURING CONSTRUCTION.



FIG. 2.—COMPLETED 24 x 10-FOOT ARCH CULVERT.

The cement hardened rapidly, so that it was not necessary to leave the centers in very long after the ring had been turned. Centers were never removed, however, in a less number of days after the masonry was completed than the number equaling the diameter of the arch in feet.

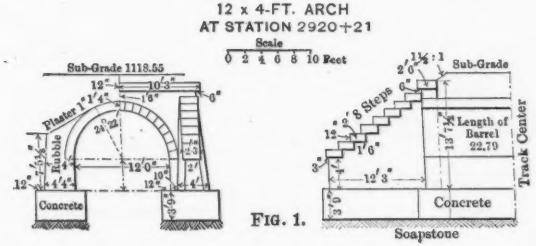


FIG. 1.

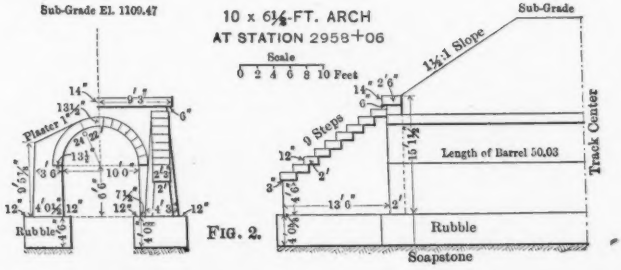


FIG. 2.

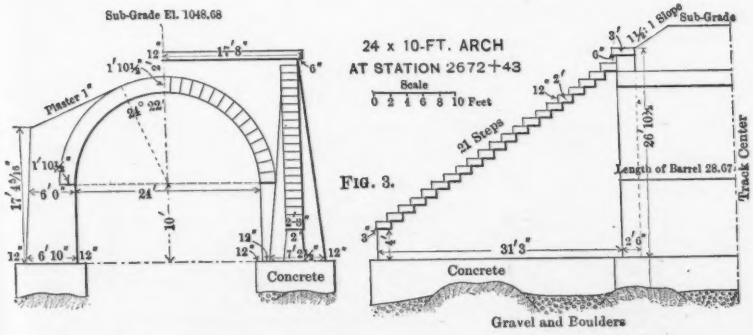


FIG. 3.

In almost every case the creek channels crossed the right of way at an angle; therefore, channel changes were made to admit and discharge the water freely. A great deal of the material from the excavation thus made was utilized in building the embankments.

DOUBLE 14 x 5½-FT. ARCH
AT STATION 2761+33

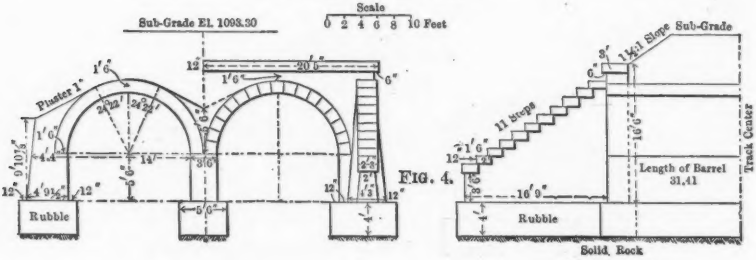


FIG. 4.

10 x 5-FT. ARCH
AT STATION 2425+40

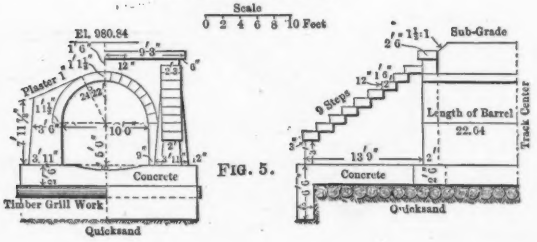


FIG. 5.

8 x 4½-FT. ARCH
AT STATION 2575+80

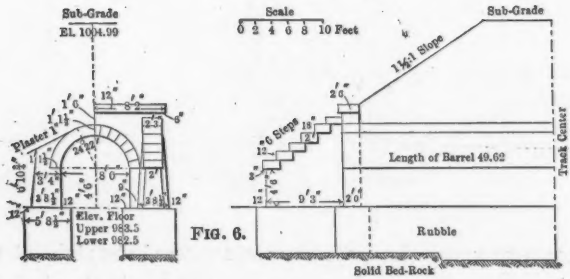


FIG. 6.

4 x 6-FT. BOX
AT STATION 2622 + 80

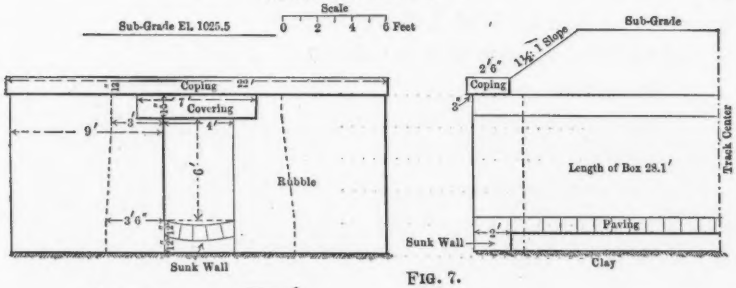
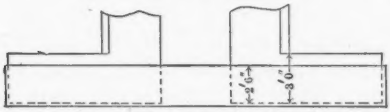


FIG. 7.



2 x 2-FT. BOX
AT STATION 2638 + 71

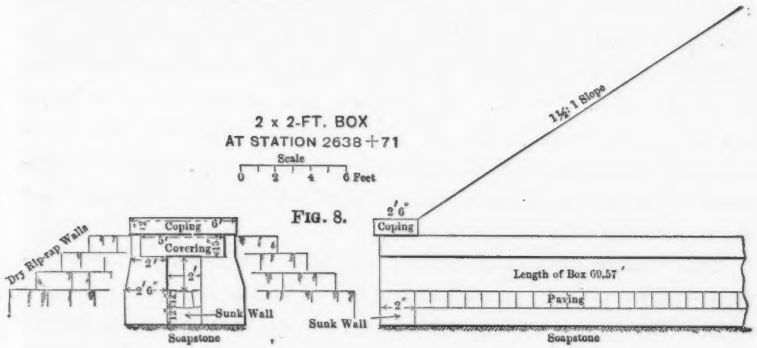


FIG. 8.

DOUBLE 3 x 3-FT. BOX
AT STATION 2710 + 08

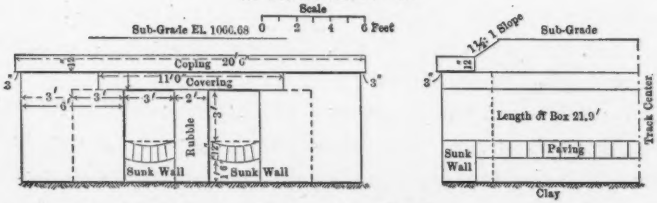
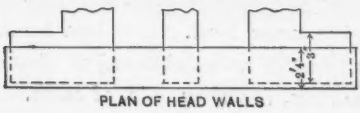


FIG. 9.



All the masonry was laid out on a grade. The writer believes in setting boxes on a grade of not less than 1 per cent. The largest arch built was set on a grade of 1.25 per cent.

The scale of wages paid is as follows:

Mason foreman	40	cents per hour.
Masons	35	" "
Quarrymen	25	" "
Mortar mixers	20	" "
Labor	17½	" "
Teams	32½ to 35	" "

The work was done on a 10-hour-day basis.

Newkirk is located on a high table land underlaid with limestone, and the water obtained from wells is too hard for boiler use and too small in quantity to supply a steam pumping plant. For these reasons the Chief Engineer decided to build a reservoir for engine water, at a place 2½ miles from town, by raising the grade line of the embankment to form a dam, thus impounding in a ravine about 93 000 000 galls. of water. The drainage area of this reservoir is 2.45 sq. miles, and the project made it necessary to excavate a new channel for Wolf Creek, 2 800 ft. long, and parallel to the railway embankment. This creek has a discharge of about 2 cu. ft. per second for about six months in the year.

The location of the high-water line made it necessary to buy outright two farms and a portion of a third, as well as change the County road. The Railway Company made 7 145 cu. yds. of embankment and built a new 56-ft. pile trestle to raise the wagon road 4 ft. above the crest of the spillway.

In building the embankment for the dam the sod was first stripped from the base and laid close to the slope stakes at the back. A core-trench 6 ft. wide and from 2 to 4 ft. deep was then dug, so as to reach the hard, impervious clay.

The embankment was put in by a steam-grader outfit, with which a wheeler outfit worked, borrowing yellow clay for the core in the center. This clay core was solidified by being trampled by men and horses and rolled continually by the wheels of the scrapers and wagons, and was carried up to the water level. The dam has a top width of 20 ft., a slope of 2½ to 1 on the water side and of 1½ to 1 on the back. It contains, approximately, 70 000 cu. yds. of earth.



FIG. 1.— DOUBLE 4 x 3-FOOT BOX CULVERT.



FIG. 2.—EXCAVATING FOR RESERVOIR SPILLWAY.

U of M

The rip-rap was composed of limestone, hauled by the construction train from a rock-cut 2 miles away. It was 18 ins. thick, and was placed on the face by hand.

The dam is perfectly water-tight, there being no seepage either through it or along the base.

The length of the spillway is 120 ft., the depth of water on the crest being calculated never to exceed 2½ ft. The length of the floor is 100 ft., and the water is discharged into a channel 20 ft. wide on the bottom and having slopes of 1 to 1, the floor being curved to keep the main current on the center line.

The construction was commenced in December, and the concreting in January. The curved sides and floor were excavated in the hard red clay on which the spillway is located, the work being done to a depth of 12 ins. below the grade stakes set for the top of the pavement. Ogee curve-forms were set for the crest wall, no trouble being caused by their moving during the progress of the work.

The concrete was made in the proportion of 1 part Portland cement, 2½ parts sand, and 4 parts crushed stone, the sand and cement being first shoveled together dry. Some difficulty was caused by the sand being partly frozen, which made it necessary to heat about one-third of the quantity used. The cost of cement, at the factory, was about $1.30 per barrel, and 576 bbls. were used.

The cost of the spillway was:

Excavation, 2 178 cu. yds.—Force account....		$1 248.33
Stone	$147.20	
Sand.....	77.54	
Royalty on stone quarried.....	15.00	
Labor.....	985.43	
Hardware	7.70	
Carpenter making forms	13.50	
Lumber for forms and sheeting.....	118.60	
Blasting powder and fuse for quarrying.....	7.50	
Grading and filling in around walls..	58.98	
		1 431.45
Total cost of excavating, grading and concreting.....		$2 679.78

To this should be added the cost of the cement, say $750.00, thus making the total cost of the work $3 429.78.

Credit is due the contractor, Mr. L. W. Lewis, of Emporia, Kans., and Mr. E. E. Lewis, his general foreman, for the successful handling of the work and the faithful way in which the specifications were followed.

The writer also wishes to acknowledge his thanks to his Assistant Engineer, Mr. H. S. Hancock, Jr., for his accurate instrument work and his unremitting attention to details.

Vol. XXIX. AUGUST, 1903. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE FATIGUE OF CEMENT PRODUCTS.

By J. L. Van Ornum, M. Am. Soc. C. E.

To be Presented October 21st, 1903.

Although the investigation has only begun, the writer believes that the importance of the subject makes it advisable to state the results of experiments (as far as obtained), made under his direction, to determine the behavior of certain Portland cement mixtures when subjected to repeated loads of a less intensity than would produce failure when once applied. Certain observed peculiarities in tests of concretes led to the conclusion that brittle engineering materials (such as stone, brick, mortars, concretes, etc.), of which cement mixtures are a fair type, possess the property of a progressive failure or "gradual fracture" which finally becomes complete under the repetition of a load well within the ultimate strength of the material. The analogy to the similar property of steel, proved by Bauschinger and Wöhler about forty years ago, is evident.

The probability of this fact was indicated to the writer last December, when some peculiar results of an investigation made on concretes at Washington University could only be explained, apparently, on the hypothesis already mentioned. The time which has since elapsed has

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

been too short for the extended investigation necessary to develop details, but results thus far obtained indicate plainly that this characteristic is true.

The experiments made were compressive tests upon neat Portland cement blocks (approximately 2-in. cubes), using a standard American brand, and crushed when four weeks old. The tests were made by Mr. Hans Schantl, of the civil engineering department, an expert experimenter. The ultimate strength was determined in the usual way, and similar blocks were subjected to certain percentages of the ultimate strength, varying from 95 to 55% of the same, the load in each case being applied and removed repeatedly until failure occurred. In all, ninety-two blocks were tested, and the average results are indicated graphically in the accompanying diagram, Fig. 1.

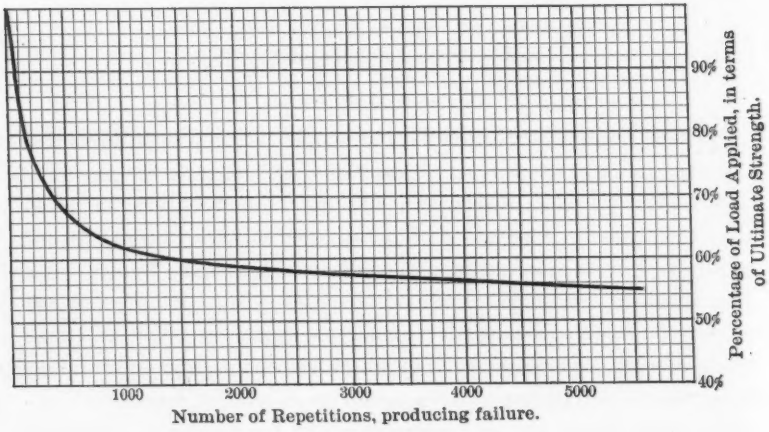


FIG. 1.

In general, the figure indicates that failure occurs under repeated loadings of much less intensity than that necessary to cause failure when once applied (the latter being the test always relied upon to judge of the strength of such a material), and that the number of repetitions necessary to cause rupture is greater for the smaller loads, as would be expected. This curve should be considered characteristic, and not precise; it does not indicate necessarily the exact relation between the number of repetitions and the corresponding intensity of load, but rather typifies the general law of "fatigue" as outlined

above. It should also be said that while time has not yet permitted similar systematic tests on concrete, yet eighteen repetition tests on 7-in. cubes indicate by their behavior that the same general law of gradual failure applies equally to concretes.

It is to be hoped that this investigation may be extended as rapidly as circumstances will allow. In determining the proper factor of safety to use, for concretes under various conditions of design, such facts would be especially pertinent. Concretes vary so widely in character and quality of materials, proportions of ingredients, and in characteristics depending upon age, conditions of loading, whether or not reinforcing metal is introduced, etc., that much time and labor will be necessary to establish the law of "fatigue" under the various conditions existing. Especial care is also necessary because of the difficulties inherent in securing definite results with cement products.

If a number of research laboratories should become interested in developing the actually existing laws and relations indicated, the securing of the useful results will be expedited.

A certain portion of this research has been undertaken by Washington University, and the writer has planned a series of experiments which will continue throughout the year in its testing laboratory. It is the intention to make public the results, as definite facts and the principles of behavior of these materials under repeated loads are developed.

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PAPERS AND DISCUSSIONS.

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DEFLECTIONS OF BEAMS WITH VARIABLE MOMENTS OF INERTIA.

Discussion.*

By Messrs. MANSFIELD MERRIMAN, C. H. LINDENBERGER and C. W. HUDSON.

Mr. Merriman.

MANSFIELD MERRIMAN, M. Am. Soc. C. E.—The speaker has read this paper with much interest, and regards it as a valuable contribution to the theory of beams. The general method of determining deflections of beams with variable moments of inertia has long been known, but this appears to be the first deduction which includes the shearing resistance of the web, as well as the tensile and compressive resistances in the flanges. The formulas, although apparently lengthy, are not difficult of application, and it is now possible to make precise computations of the deflection of the ends of a plate-girder drawbridge with variable cross-sections.

The early investigators regarded the influence of the shearing stresses on the deflection as too small to be considered. For a long beam of constant cross-section this is often the case, but when the beam is short the influence of shearing may be very marked. A plate-girder is a case where the shearing effects should not be neglected, and it appears that the influence of variable cross-section produces changes in the reactions and bending moments which are unexpected. It may be noted, moreover, that the influence of shear seems to increase with investigation; every extended analysis seeming to make it slightly greater than before.

The work in the flanges due to shearing is but a small part of that

* Continued from May, 1903, *Proceedings*. See March, 1903, *Proceedings* for paper on this subject by C. W. Hudson, M. Am. Soc. C. E.

in the web, as the author's investigation fully shows, and hence it may properly be neglected. The author's treatment of the work in the web, regarding the shear to increase toward the neutral axis, is in the right direction, but after this was done it is not clear why the coefficient, $\frac{2}{3}$, was not retained in the general formula on page 278.* Neglect of the shear in the flanges does not appear to be balanced by neglect of the actual distribution of the shear in the web. The effect of these assumptions on the deflection is not great, but the effect on the reactions and bending moments in the cases considered may perhaps be a considerable one. The author's very excellent investigation cannot, therefore, be regarded as final in regard to the influence of the shearing stresses. Mr. Merriman.

In reference to this it may be observed that the common theory of beams, in which the stresses are represented by horizontal tensions and compressions and by vertical shears, is an approximation only. At any point in the beam there really act tensile and compressive stresses at right angles to each other, but these are not horizontal, except at the upper and lower surfaces, while the shearing stresses are not vertical, but oblique. The actual condition is hence one of great complexity, and it may be considered as surprising that the common theory gives results for common cases so closely agreeing with practice. In extreme cases, however, the theory must be supplemented to meet the unusual conditions. The paper, therefore, treats, not only with a practical engineering problem, but with an important scientific question.

C. H. LINDENBERGER, Assoc. Am. Soc. C. E. (by letter).—The writer is glad to see that Mr. Hudson is urging reform in the computation of girders with variable moments of inertia. Mr. Lindenberger.

What is wanted is mainly, not new formulas, but simpler methods of applying those already in existence; for, in the writer's experience, it requires only a small amount of mental confusion to discourage the ordinary bridge computer. This is not a fault of intellect, but is due to the fact that computation is a task, and not a luxury, with him, and he is obliged to crowd a great deal into a day's work, under circumstances which practically prohibit studying out abstruse problems.

The writer was also much gratified to find that Mr. Hudson's formula, originally due to Professor Fraenkel, agrees with that of the writer, published in 1891. The agreement is not a mere general agreement, but a precise and exact identity, in any and every particular when concentrated loads and vertical deflections only are considered. The fact of this identity can be demonstrated analytically, by developing the integral $\int \frac{M\,m\,dx}{E\,I}$ for the cases given; but the question is of only theoretical importance, and hardly interesting enough to print in the *Transactions*.

* *Proceedings*, Am. Soc. C. E., for March, 1903.

Mr. Lindenberger.

The formula which the writer calls his is merely the old three-moment theorem applied to girders with variable moments of inertia, and is originally due to Professor Weyrauch in his "Continuirlichen und Einfachen Träger." The writer is indebted to Malverd A. Howe, M. Am. Soc. C. E., for his knowledge of the subject, as given in Mr. Howe's "Continuous Girder." This formula* is a rearrangement and simplification of these others that preceded it, and, of course, gives, absolutely and rigorously, identical results. The integrals for uniform load were not developed.

The problem of simplification, for the hurried and busy computer, has about reached its limit, as far as analysis is concerned. All that remains is to calculate a case, with all its numerical details, and show that Greek letters and signs of summation are not nearly as complicated as they appear to be.

It will be shown that not only is the formula complete, as a method of calculation, but also, that every single detail of the process can be checked by a graphical method, and this is not possible by any other formula.

The girder selected is the one detailed by Mr. Hudson:† 101½ ins. deep and 156 ft. long. It will be supposed to rest on two supports, and the deflection at a point 70 ft. from the left end is wanted. Now, it may be considered as a girder continuous over three supports, provided it be assumed that the support at the deflection point has sunk, so that the girder just touches, and the reaction is zero.

Then l_1 = first span = 70 ft.;

l_2 = second span = 86 ft.;

ε_v and ε_{v-1} are the horizontal co-ordinates of two points, respectively, of this girder, between which the moment of inertia is constant;

I_v is the moment of inertia between these points;

M_2 is the moment at the deflection point, and is positive when there is tension on the upper flange;

E is the modulus of elasticity = 4 176 000 000 lbs. per square foot.

$$\Delta\, \varepsilon_v = \frac{\varepsilon_v - \varepsilon_{v-1}}{I_v}$$

$$\Delta\, \varepsilon^2_v = \frac{\varepsilon_v{}^2 - \varepsilon^2{}_{v-1}}{I_v}$$

$$\Delta\, \varepsilon^3_v = \frac{\varepsilon^3{}_v - \varepsilon^3{}_{v-1}}{I_v}$$

$$E\,\gamma_v = \frac{\Delta\, \varepsilon^3_v}{3\, l^2_r}$$

$$E\,\lambda_v = \frac{\Delta\, \varepsilon^2_v}{2\, l_r} - \frac{\Delta \varepsilon^{\,3}_v}{3\, l^2_r}$$

*Journal of the Franklin Institute, January, 1891.

†Proceedings, Am. Soc. C. E., for March, 1903, p. 274.

Mr. Lindenberger.

$$E\,\tau_v = \Delta\,\varepsilon_v - \frac{\Delta\,\varepsilon^2_v}{l_r} + \frac{\Delta\,\varepsilon^3_v}{3\,l^2_r}$$

Σ is the sign of summation.

Take the sum of the above from end to end of the rth span; then

$$G_r = \sum_o^l \gamma_v, \qquad L_r = \sum_o^l \lambda_v, \qquad T_r = \sum_o^l \tau_v$$

P_r is a load in the rth span. In this case $P_1 = 40\,000$ lbs.; $P_2 = 20\,000$ lbs.

A_r is the distance of a weight in the rth span from its left support. In this case $a_1 = 47$ ft., and $a_2 = 25$ feet.

$$\frac{B_1}{P_1} = (l_1 - a_1) \sum_o^{a_1} \gamma_v + a_1\,(L_1 - \sum_o^{a_1} \lambda_v)$$

$$\frac{A_2}{P_2} = (l_2 - a_2) \sum_o^{a_2} \lambda_v + a_2\,(T_2 - \sum_o^{a_2} \tau_v)$$

h_2 is the deflection, positive downward.

The following definitions relate only to the graphical method, but it is necessary to give some idea of them here, in order to explain the necessity for a change in the arrangements of the moments of inertia.

θ, m, and J, are purely arbitrary quantities used only in the graphical calculation.

$\theta = 6\,E$ multiplied by an arbitrary moment of inertia, here taken as 30 ft. (four dimensions). Its use is to eliminate E and to obtain linear quantities. Hence $\theta = 180\,E$.

It may seem somewhat queer to say that the unit of force is also the unit of length, viz., 1 ft.; but this is what must be done here, since E is eliminated. Everything is measured in feet.

J is the pole distance of a force polygon for forces as described below. It is here taken at 30 ft.

m is the width of a right parallelogram, the length of which is the length of the span, and is here assumed to be 10 ft. This parallelogram is divided into two main triangles by one of its diagonals. Each of these triangles is divided by vertical lines, at the points where the moments of inertia change values, into smaller subdivisions, viz., an end triangle and one or more trapezoids. The areas of these smaller subdivisions divided by their respective corresponding girder's moment of inertia, are reduced to linear quantities and are considered as vertical forces acting through the center of gravity of the areas from which they are derived. The moments of these forces, with respect to the supports, are proportional either to γ_v, λ_v or τ_v, according to which support, or which half of the parallelogram, is taken. The moments of the forces, and therefore γ_v, λ_v and τ_v, are found by constructing an equilibrium polygon and prolonging the bounding lines to the verticals through the supports, the same as any ordinary equilibrium polygon.

Mr. Lindenberger.

It will be plain from this that to obtain G_r, L_r and T_r the end sides of this equilibrium polygon are prolonged to the verticals through the supports. Now, if the arrangement as given by Mr. Hudson is examined, it will be found that part of the girder, the moment of inertia of which is 24.96, has only 3 ft. in the first span and 1 ft. in the second span. The sides of the equilibrium polygons at the right end of the first span and the left end of the second span would therefore be entirely too short to prolong to the verticals through the supports. In the first span, therefore, two parts are consolidated, and the moment of inertia used $= \frac{20.96 \times 30 + 24.96 \times 3}{33} = 21.32$. Again, in the second span we have the 24.96 section, on the left, 1 ft. long; then the 29.08 section, 14 ft. long; then another 24.96 section, 4 ft. long. In order to make the drawing clear and distinct all these were consolidated into a section the moment of inertia of which is $\frac{24.96 \times 5 + 29.08 \times 14}{19} = 28$. In practical work, on a larger scale, it would not be necessary to go to these extremes in either span; but in a drawing, in which the subject is illustrated and explained, everything should be clear and distinct.

The error due to these assumptions has been duly calculated, by the tabular method explained below, and is only about $\frac{1}{40}$ of 1 per cent.

The theorem of three moments* assumes the following form for this case:

$$h_2 = \frac{l_1 l_2}{l_1 + l_2}\Big(-M_2 (G_1 + T_2) + A_2 + B_1\Big).$$

Moments causing tension on the upper flange are considered positive, and deflections are positive downward.

Since this girder is in reality only a simple girder with reaction zero at the middle support, we can at once compute M_2 thus: The reaction at the left end of the girder

$$= \frac{1}{156}\Big(20\,000 \times 61 + 40\,000 \times 109\Big) \text{ lbs.} = 35\,769 \text{ lbs.}$$

$$M_2 = -(35\,769 \times 70 - 40\,000 \times 23) = -1\,583\,830,$$

measured in foot-pounds.

We will now proceed to calculate G_1, L_1 and B_1 from the following table:

FIRST SPAN.

v	ϵ_v	I_v	$\Delta\epsilon^2 v$	$\Sigma\Delta\epsilon^2 v$	$\Delta\epsilon^3 v$	$\Sigma\Delta\epsilon^3 v$
1.....	37	17.06	80.2462	.....	2 969.1090	.....
2.....	70	21.32	165.6191	245.8653	13 712.3358	16 681.4448

* *Journal* of the Franklin Institute, January, 1891.

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$$E\,G_1 = \frac{16\,681.4448}{14\,700} = 1.1348;$$

$$E\,L_1 = \frac{245.8653}{140} - \frac{16\,681.4448}{14\,700} = 1.7562 - 1.1348 = 0.6214.$$

To compute $\sum_{o}^{a_1} \gamma_v$ and $\sum_{o}^{a_1} \lambda_v$, we must find the functions like those in the table between the points, $\varepsilon = a_1 = 47$, and $\varepsilon = \varepsilon_1 = 37$; thus,

$$\Delta\,\varepsilon^2 = \frac{(47)^2 - (37)^2}{21.32} = 39.3996;$$

$$\Delta\,\varepsilon^3 = \frac{(47)^3 - (37)^3}{21.32} = 2\,493.9024.$$

$$E\sum_{o}^{a_1} \gamma_v = \frac{2\,969.1090 + 2\,493.9024}{14\,700} = 0.3716;$$

$$E\sum_{o}^{a_1} \lambda_v = \frac{80.2462 + 39.3996}{140} - \frac{2\,969.1090 + 2\,493.9024}{14\,700}$$

$$= 0.8546 - 0.3716 = 0.4830.$$

Hence,

$$E\,B_1 = 40\,000\,[23 \times 0.3716 + 47\,(0.6214 - 0.4830)] = 602\,064.$$

The next is the calculation of L_2, T_2, and A_2, which is done from the following table:

SECOND SPAN.

v	ϵ_v	I_v	$\Delta\,\epsilon_v$	$\Sigma\,\Delta\,\epsilon_v$	$\Delta\,\epsilon^2 v$	$\Sigma\,\Delta\,\epsilon^2 v$	$\Delta\,\epsilon^3 v$	$\Sigma\,\Delta\,\epsilon^3 v$
1...	19	28.	0.6786	.....	12.8929	.....	244.9643	.....
2...	49	20.96	1.4313	2.1099	97.3282	110.2211	5 285.7824	5 530.7467
3...	86	17.06	2.1688	4.2787	292.7902	403.0113	30 387.2802	35 918.0269

$$E\,L_2 = \frac{403.0113}{172} - \frac{35\,918.0269}{22\,188} = 2.3431 - 1.6188 = 0.7243;$$

$$E\,T_2 = 4.2787 - \frac{403.0113}{86} + \frac{35\,918.0269}{22\,188} = 4.2787 - 4.6862 + 1.6188$$

$$= 1.2113.$$

In order to compute A_2, we must compute $\Delta\,\varepsilon$, $\Delta\,\varepsilon^2$, and $\Delta\,\varepsilon^3$ for that part of the girder between $\varepsilon = a_2 = 25$ ft., and $\varepsilon = 19$ ft., thus:

$$\Delta\,\varepsilon = \frac{25 - 19}{20.96} = 0.2863;$$

$$\Delta\,\varepsilon^2 = \frac{(25)^2 - (19)^2}{20.96} = 12.5954;$$

$$\Delta\,\varepsilon^3 = \frac{(25)^3 - (19)^3}{20.96} = 418.2252;$$

$$E\sum_{o}^{a_2} \lambda_v = \frac{12.8929 + 12.5954}{172} - \frac{244.9643 + 418.2252}{22\,188}$$

$$= 0.1482 - 0.0299 = 0.1183;$$

$$E\sum_{o}^{a_2} \tau_v = 0.6786 + 0.2863 - \frac{12.8929 + 12.5954}{86} + \frac{244.9643 + 418.2252}{22\,188}$$

$$= 0.6786 + 0.2863 - 0.2964 + 0.0299 = 0.6984;$$

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$$E A_2 = 20\,000\,[61 \times 0.1183 + 25\,(1.2113 - 0.6984)] = 400\,776.$$

Substituting all values in the three-moment theorem, previously mentioned, as applied to this problem, we get

$$h_2 = \frac{70 \times 86\,[1\,583\,830\,(1.1348 + 1.2113) + 400\,776 + 602\,064]}{(70 + 86)\,4\,176\,000\,000} \text{ ft.}$$

$$= 0.0436 \text{ ft.} = 0.5232 \text{ in.}$$

In the girder, as designed by Mr. Hudson, the deflection would be 0.04359 ft.

The reader who examines the original article, in the *Journal* of the Franklin Institute, will find some changes introduced which the writer believes will facilitate calculation. In particular, instead of θ_{v-1}, which is rather confusing,* the writer has substituted $6\,E\,I_v$ here, which represents the same idea, and has changed the formula so that no double work is done by first multiplying by and then dividing by $6\,l^2_r$, $6\,l_r$, etc.

While the above completes the tabular method, there are some data which are useful in checking up the graphical method; or, *per contra*, in checking the tabular method from the graphical. The figures of the tabulation may be checked from the graphical method, as will be shown later.

From the table for the "first span" we get:

$$E\gamma_1 = 0.202; \qquad E\lambda_1 = 0.3712;$$
$$E\gamma_2 = 0.9328; \qquad E\lambda_2 = 0.2502.$$

Also, from the table for the "second span":

$$E\lambda_1 = 0.064; \qquad E\tau_1 = 0.5397;$$
$$E\lambda_2 = 0.3276; \qquad E\tau_2 = 0.5378;$$
$$E\lambda_3 = 0.3327; \qquad E\tau_3 = 0.1338.$$

The following is an explanation of the graphical method. Fig. 12 represents the method of calculating L_1, G_1 and B_1. In Fig. 13, L_2, T_2 and A_2 are computed. The upper part, in each, shows the girder, its moments of inertia, and its load. Below this is the triangle, half of the parallelogram previously mentioned. We are to calculate the required quantities from the areas of the subdivisions of this triangle. Underneath the triangle is the equilibrium polygon, and on the left is the force polygon, the pole distance of which is J (= 30 ft.), both of which have also been described previously in a general way. It should be noted that in Fig. 12 the toe of the triangle is on the left side, while in Fig. 13 it is the reverse.

If v is the number of any section, either in Fig. 12 or Fig. 13, then the formula for the ordinate, $E_v\,C_v$ is

$$E_v\,C_v = \frac{E\,I_v\,l_r}{\theta};$$

and

$$\theta = 180\,E.$$

* See Howe's "Continuous Girder" for subscript copied.

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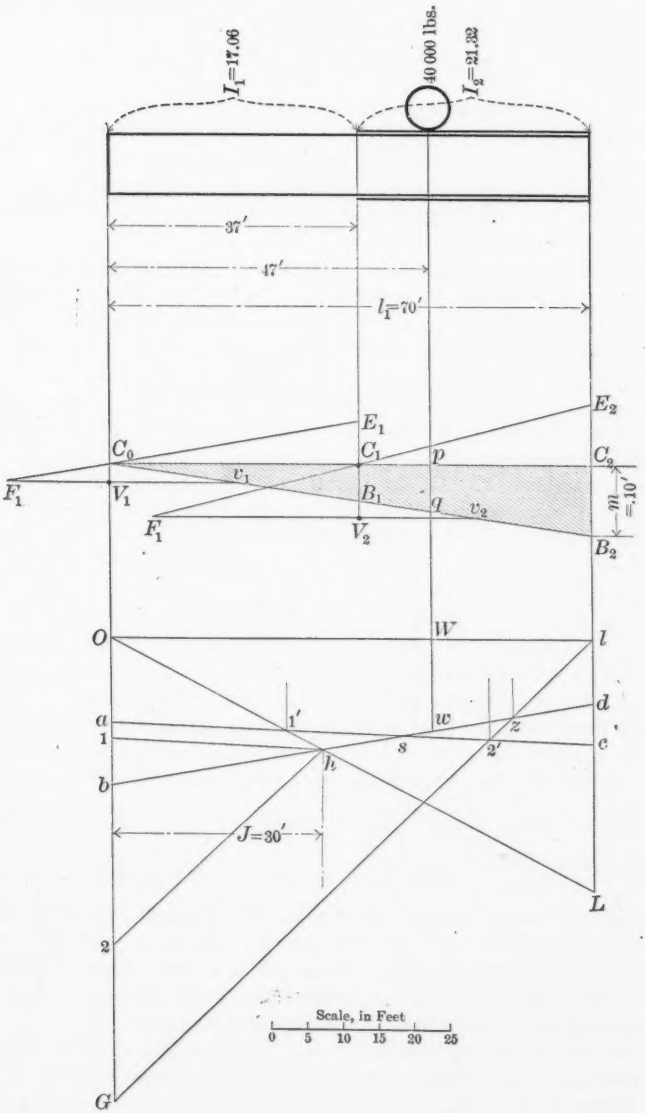


FIG. 12.

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We will commence with these in Fig. 12:

$$E_1 C_1 = \frac{E \times 17.06 \times 70}{180\ E} = 6.63 \text{ ft.};$$

$$E_2 C_2 = \frac{E \times 21.32 \times 70}{180\ E} = 8.29 \text{ ft.}$$

v_1 and v_2, respectively, are the middle points of $C_0 B_1$ and $B_1 B_2$. From each of these points draw a horizontal line. The sloping line, $E_1 C_0$, intersects the horizontal line drawn through v_1 at F_1. V_1 is on the vertical through C_0. In a similar manner, the sloping line, $E_2 C_1$, intersects the horizontal line drawn through v_2 at F_2, and V_2 is on the vertical through C_1.

$F_1 V_1$ and $F_2 V_2$ are to be considered as vertical forces acting through the centers of gravity of the respective areas to which they belong. Thus $F_1 V_1$ acts through the center of gravity of the triangle, $C_0 C_1 B_1$. $F_2 V_2$ acts through the center of gravity of the trapezoid, $C_1 C_2 B_2 B_1$. These forces are directly proportional to the areas to which they belong, divided by the respective girder's moment of inertia. It is a matter of prime importance that the exact center of gravity of these trapezoids be computed accurately when they are relatively large, like this one. An old method of doing this graphically is here described, not because engineers may not know it, but because most people easily forget these things when they are out of their line. It is shown in Fig. 14. $A\ C\ D\ B$ is the trapezoid, and $H\ L$ a line that bisects the sides, $A\ B$ and $C\ D$. On $A\ B$, produced, lay off $A\ E = C\ D$, and on $C\ D$, produced, lay off $D\ F = A\ B$, and draw $E\ F$. Then G, at the intersection of $E\ F$ and $H\ L$, is the center of gravity.

Construct the force polygon, $O-1-2-h$, by laying off $O-1 = F_1 V_1$ and $1-2 = F_2 V_2$, and assume a pole the perpendicular distance of which from the force line $(= J)$ is here assumed at 30 ft. From this the equilibrium polygon, $O-1'-2'-l$, is constructed in the usual manner. Prolong the end sides to intersect the verticals through the supports at G and L; then $O\ G = \frac{m\ \theta\ G_1}{J}$, and $l\ L = \frac{m\ \theta\ L_1}{J}$. Now, this factor, $\frac{m\ \theta}{J} = \frac{10 \times 180\ E}{30} = 60\ E$, and, therefore, if the work done is exactly correct, $O\ G$ should measure 68.088 ft., and $l\ L$ should also be 37.284 ft. Of course, such accuracy is not possible. The figures of these drawings, however, are invariably carried out to several places of decimals, far beyond the ability of the draftsman, even if using a microscope, for thereby the subject is illustrated more accurately.

The next is the calculation of B_1. The vertical through the load, P_1, intersects the closing line of the equilibrium polygon at W, and the triangle, $C_0\ C_2\ B_2$, in a line, $p\ q$. The center of gravity of the trapezoid, $C_1\ p\ q\ B_1$, is in a vertical through s. The center of gravity of the trapezoid, $p\ q\ B_2\ C_2$, is in a vertical through z. Both these

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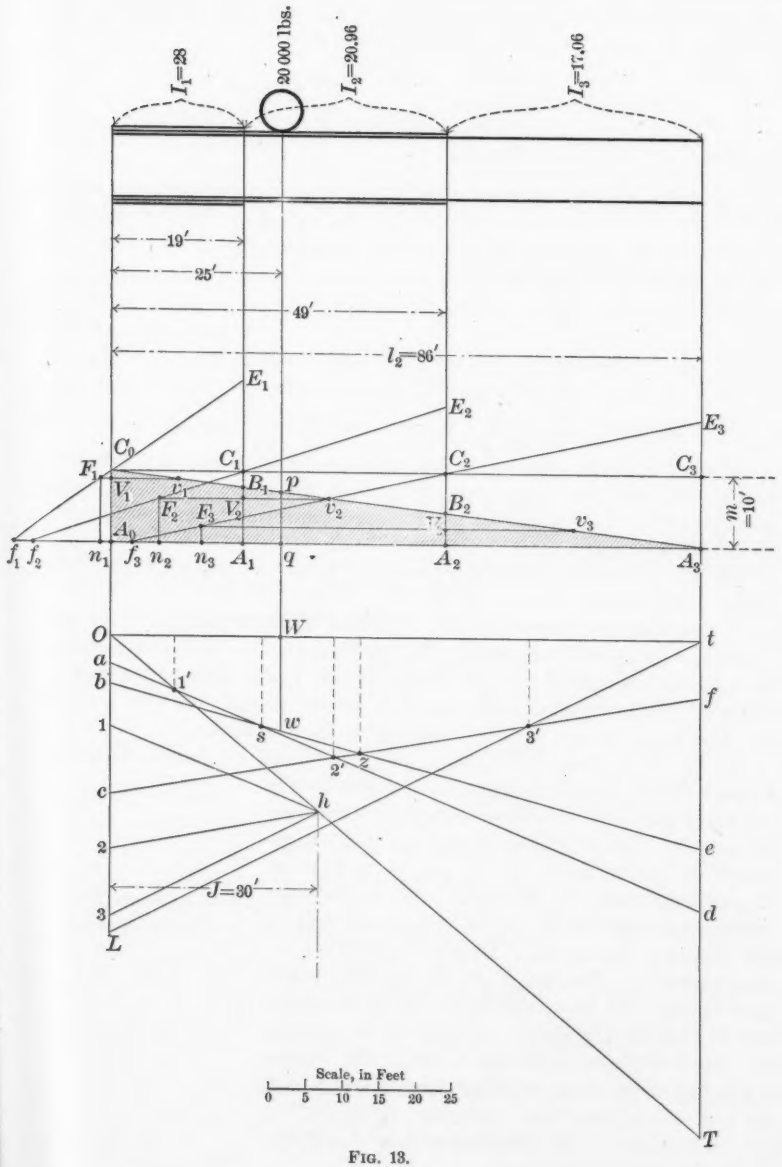


FIG. 13.

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points are on the bounding lines of the equilibrium polygon. Draw $s\,z$ and produce it both ways to the verticals through the supports at b and d. It intersects the vertical through W at w.

Then

$$W\,w = 12.9014 \text{ ft.} = \frac{m\,\theta\,B_1}{J\,l_1\,P_1} = \frac{10 \times 180\,E \times B_1}{30 \times 70 \times 40\,000},$$

whence $B_1 = \dfrac{602\,064}{E}$, as found previously.

Attention is now called to Fig. 13, representing the second span, and from which we are to calculate L_2, T_2, and A_2. The formula for computing $E_1\,C_1$, $E_2\,C_2$, etc., applies, as heretofore given, and we therefore deduce (omitting E):

$$E_1\,C_1 = \frac{28 \times 86}{180} = 13.38 \text{ ft.}$$

$$E_2\,C_2 = \frac{20.96 \times 86}{180} = 10.01 \text{ ft.}$$

$$E_3\,C_3 = \frac{17.06 \times 86}{180} = 8.15 \text{ ft.}$$

$F_1\,V_1$, $F_2\,V_2$, etc., are computed graphically in the same manner as in Fig. 12, and they are used for similar purposes. That is, when necessary, G_2, B_2, and incidentally L_2, are computed from these in the same way as in Fig. 12.

The lines that are used as forces here, however, are not these, but are $f_1\,n_1$, $f_2\,n_2$, etc.

The manner of computing any of these will be explained from one example. Suppose the point, F_2, is found. Produce the sloping line, $E_2\,C_1$, through F_2 until it intersects the bottom line of the parallelogram at f_2. A vertical through F_2 intersects this bottom line at n_2. The lines, $f_1\,n_1$, $f_3\,n_3$, are found in the same manner.

These lines, $f_1\,n_1$, $f_2\,n_2$, etc., are considered as forces, and are directly proportional to the areas to which they belong divided by the respective girder's moment of inertia. These subdivisional areas are contained in the triangle, $C_0\,A_3\,A_0$. $f_1\,n_1$ belongs to the trapezoid, $C_0\,B_1\,A_1\,A_0$. $f_2\,n_2$ belongs to the trapezoid $B_1\,B_2\,A_2\,A_1$. $f_3\,n_3$ belongs to the triangle, $B_2\,A_3\,A_2$. This is a different arrangement from that for $F_1\,V_1$, $F_2\,V_2$, etc., as the subdivisions for these are taken from the other half of the parallelogram. The lines, $f_1\,n_1$, $f_2\,n_2$, etc., are considered as acting through the center of gravity of the areas to which they belong, and are laid off in the force polygon: $f_1\,n_1 = 0$–1; $f_2\,n_2 = 1$–2, etc. The pole distance $= J = 30$ ft.

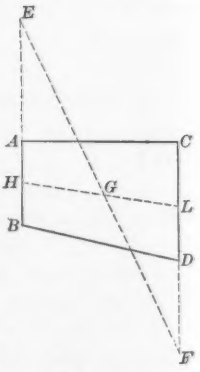


FIG. 14.

The equilibrium polygon, $O - 1' - 2' - 3' - t$, is constructed in the usual manner. Prolong

the end sides of this equilibrium polygon to the verticals through the supports, intersecting them at L and T, Mr. Lindenberger.

Then

$$O\,L = \frac{m\,\theta\,L_2}{J} = 43.458 \text{ ft.}$$

$$T = \frac{m\,\theta\,T_2}{J} = 72.678 \text{ ft.}$$

The next is the calculation of A_2. The vertical through the load, P_2, intersects the closing line of the equilibrium polygon at W, and the triangle, $C_0\,A_3\,A_0$, in a line, $p\,q$.

The center of gravity of the trapezoid, $B_1\,p\,q\,A_1$, is in a vertical through s, and the center of gravity of the trapezoid, $p\,B_2\,A_2\,q$, is in a vertical through z. Both these points are on the sides of the equilibrium polygon.

Draw $s\,z$ and produce it to b and ε on the verticals through the supports. It intersects the vertical through W at w. Then

$$W\,w = \frac{m\,\theta\,A_2}{J\,l_2\,P_2} = \frac{10 \times 180\,E \times A_2}{30 \times 86 \times 20\,000} = 13.9806 \text{ ft.}$$

Hence,

$$A_2 = \frac{400\,776}{E}, \text{ as previously found.}$$

The graphical computation is now complete, provided no mistake has been made. If the drawing and the tabular calculation disagree, it is well to check one against the other.

Commence with the first span

$$O\,a = \frac{m\,\theta}{J}\,\gamma_1 = 12.12 \text{ ft.}$$

$$O\,b = \frac{m\,\theta}{J}\sum_o^{a_1}\gamma = 22.296 \text{ ft.}$$

$$c\,L = \frac{m\,\theta}{J}\,\lambda_1 = 22.272 \text{ ft.;}$$

$$d\,L = \frac{m\,\theta}{J}\sum_o^{a_1}\lambda = 28.98 \text{ ft.}$$

$$F_1\,V_1 = 14.7391 \text{ ft.}$$

$$F_2\,V_2 = 30.4198 \text{ ft.}$$

Now refer to Fig. 13.

$$O\,a = \frac{m\,\theta}{J}\,\lambda_1 = 3.834 \text{ ft.}$$

$$O\,b = \frac{m\,\theta}{J}\sum_o^{a_3}\lambda = 7.098 \text{ ft.}$$

$$O\,c = \frac{m\,\theta}{J}\,(\lambda_1 + \lambda_2) = 23.496 \text{ ft.}$$

$$T\,d = \frac{m\,\theta}{J}\,\tau_1 = 32.382 \text{ ft.;}$$

$$T\,\varepsilon = \frac{m\,\theta}{J}\sum_o^{a_3}\tau = 41.904 \text{ ft.;}$$

$$T\,f = \frac{m\,\theta}{J}\,(\tau_1 + \tau_2) = 64.65 \text{ ft.}$$

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$f_1 n_1 = 12.6344$ ft.; $f_2 n_2 = 18.1138$ ft.; $f_3 n_3 = 9.7646$ ft.
$F_1 V_1 = 1.5689$ " $F_2 V_2 = 11.8436$ " $F_3 V_3 = 35.6289$ "
$f_1 A_0 = 14.2033$ " $f_2 A_1 = 29.9574$ " $f_3 A_2 = 45.3935$ "

From the above, considerable checking could be done, but the best method is to check the tables directly, thus:

If v is the number of a section, then

$$f_v A_{v-1} = \frac{m\ 0}{E\ l_r} \Delta\ \varepsilon_v$$

To illustrate this, and check the table, let $v = 2$, in Fig. 13; then

$$f_2 A_1 = 29.9574 \text{ ft.} = \frac{10 \times 180\ E}{E \times 86} \times \Delta\ e_2 \text{ ft.};$$

whence $\Delta\ \varepsilon_2 = 1.4313$, as in the table.

Again,

$$F_v V_v = \frac{m\ 0}{2\ E\ l^2_r} \Delta^2_v,$$

and, making $v = 2$,

$$F_2 V_2 = 11.8436 \text{ ft.} = \frac{10 \times 180\ E}{2 \times E \times 7\,396} \times \Delta\ \varepsilon^2_2 \text{ ft.}$$

$\Delta\ \varepsilon^2_2 = 97.3282$, as in the table.

$\Delta\ \varepsilon^3_v$ can easily be checked from the values of γ_v in Fig. 12. In Fig. 13, however, a different plan will have to be adopted. Let $F_v V^a$ be called q^1_v and let X_v be the distance of the center of gravity of the subdivisional area from the left support, then

$$q^1_v X_v = \frac{m\ 0}{3\ E l^2_r} \Delta\ \varepsilon^3_v.$$

In Fig. 13, let $v = 2$. $F_2 V_2 = 11.8436$ ft. The area to which it belongs is the trapezoid, $C_1 C_2 B_2 B_1$, and $X_v = 36.2059$ ft.

Then

$$11.8436 \times 36.2059 = \frac{10 \times 180\ E}{3\ E \times 7\,396} \times \Delta\ \varepsilon^3_2$$

Whence $\Delta\ \varepsilon^3_2 = 5\,285.7824$, as in the table.

There is another method of calculating G_1, L_1, L_2, T_2, which must be mentioned.

If the lines that are taken as forces are considered as such, then there must be reactions at the supports due to these forces. Therefore, in Fig. 12, the reaction at the left support $= \frac{m\ 0}{l_1} L_1 = 15.9786$ ft. The reaction at the right support $= \frac{m\ 0}{l_1} G_1 = 29.1803$ ft. In Fig. 13, the reaction at the left support $= \frac{m\ 0}{l_2} T_2 = 25.325$ ft. That at the other support $= \frac{m\ 0}{l_2} L_2 = 15.193$ ft. The unit of force = the unit of length = 1 ft. These reactions are found in the usual manner by drawing a line from the pole parallel to the closing line of the equilibrium polygon.

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The reader may notice the ill-conditioned triangles about the parallelogram. These were caused by too large a value of θ, but the latter could not be diminished without increasing the vertical dimensions of the drawing. The proper value of θ, is when $E_1 C_1$, $E_2 C_2$, etc., have such values that $E_1 C_0$, $E_2 C_1$, etc., slope about at an average angle of 45 degrees. The product, $m \times \theta$, is determined by the smallest length of line that is to be inserted in the force polygon. Finally, $\frac{m\theta}{J}$ is determined by the intercepts on the verticals.

A little practice will enable one to assume proper values.

When $l_1 = l_2$, and the girder is symmetrical with reference to its center, the problem is simpler. $G_1 = T_2$; $L_1 = L_2$. Also, if any two loads on these two different spans are at equal distances from the center, then, for these, $A_2 = B_1$. This is a very common case, and one in which only half the girder need be calculated.

It is the experience of everyone that an illustration giving numerical results will do more to clear up difficulties than any amount of analytical formulas. This work, therefore, should have been done long ago, but was not, for several very good reasons. The writer thinks that the most important practical difficulties that would confuse a computer have been pretty thoroughly explained.

Mr. Hudson.

C. W. Hudson, M. Am. Soc. C. E. (by letter).—It was not the writer's intention to consider the deformations due to the auxiliary load of unity, in his derivation of

$$\Delta = \int_0^l \frac{M m \, d x}{E I} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

This expression is obtained by making the internal work,

$$W = \int_0^l \frac{M m \, d x}{2 E I} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

equal to the external work $W = \frac{\Delta}{2}$ $\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

The consideration of the increased deformations of the fibers, due to the load of unity, would increase the work of the internal stresses by exactly the same amount that the consideration of the increased deflection due to the load of unity would increase the work of the external force.

This statement appears axiomatic and therefore needs no proof.

To overcome any seeming obscurity, the foregoing statement is proved by the writer, as follows:

Let Δ_1 = the deflection of the point of application of the force of unity;

λ_1 = the change in length of any fiber due to the force of unity;

$= \frac{m \, y \, d x}{E I}$, as was shown for the given loading.

Mr. Hudson.

The total change of length of any fiber now

$$= \frac{M\,y\,d\,x}{E\,I} + \frac{m\,y\,d\,x}{E\,I} = (M+m)\frac{y\,d\,x}{E\,I},$$

and the internal work throughout the beam,

$$W = \int_o^l \frac{M\,m\,d\,x}{2\,E\,I} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The total deflection desired, now $= \Delta + \Delta_1$, and the external work done by the force of unity $= (\Delta + \Delta_1) \times \frac{1}{2}$ ..... (20)

Making Equation (10) = Equation (20), we have

$$\Delta + \Delta_1 = \int_o^l \frac{M\,m\,d\,x}{E\,I} + \int_o^l \frac{m^2\,d\,x}{E\,I};$$

but $\Delta_1 = \int_o^l \frac{m^2\,d\,x}{E\,I}$, therefore $\Delta = \int_o^l \frac{M\,m\,d\,x}{E\,I}$.

That the deflection of any point in a simple beam with either constant or variable moment of inertia can be more easily determined from $\Delta = \int_o^l \frac{M\,m\,d\,x}{E\,I}$, than from $\frac{d\,y^2}{d\,x^2} = \frac{M}{E\,I}$, can very readily be seen. The algebraic work in the solution, in general terms, of comparatively simple problems by means of the second of the foregoing being very laborious, it is not impossible.

The writer is sorry that the time at his disposal did not permit of his making a determination of the amount of work done by the shearing stresses on the vertical legs of the flange angles and on the large vertical side-flange plates in the girder of Case II. He feels sure that, for this case, neglecting this work at least balances the omission of the coefficient $\frac{8}{5}$. For the girder of Case I it would have been more accurate to have used this coefficient, and the formula for its investigation would therefore more nearly be

$$\Delta = \int_o^l \frac{M\,m\,d\,x}{E\,I} \times 3 \int_o^l \frac{S\,s\,d\,x}{E\,A\,w}.$$

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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PROGRESS REPORT OF SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT.

Discussion.*

By SANFORD E. THOMPSON, Assoc. M. Am. Soc. C. E.

Mr. Thompson.

SANFORD E. THOMPSON, Assoc. M. Am. Soc. C. E. (by letter).—The Committee has very properly confined itself to the consideration of the tests which most readily determine whether the quality of the cement is suitable for use in general construction. There are certain other tests, chiefly those of compression, flexion, adhesion, porosity and permeability, which are often made to investigate special qualities of a cement or mortar, or for scientific research. Uniformity in such tests permits comparisons of results obtained by different experimenters.

The Report of the "Commission des Methodes d'Essai des Matériaux de Construction," in 1893, while agreeing closely in fundamental points with the methods adopted by our Committee, covers a larger field, and specifies standards for all kinds of tests. The Sub-Committee which performed the direct labors of the investigation leading up to the general report was composed of MM. Durand-Claye, Alexandre, Candlot, Debray, Feret, Le Chatelier, Ribaucour, Simeon, and Viallet, each one of these men being called upon to investigate certain lines. Since these names rank so high in connection with the subject under consideration, and their conclusions on the more common tests are in such accord with those of our Committee, it

* This discussion (of the Report of the Special Committee on Uniform Tests of Cement, printed in *Proceedings* for January, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to September 25th, 1903, will be published subsequently.

Mr. Thompson. would appear that we might avail ourselves of their recommendations, with slight modifications to adapt the measurements to our standards.

Compressive Strength.—The special report to the French Commission on compression tests was made by M. P. Simeon.

The Commission reached the conclusion that the briquettes which had been broken in halves by tension should be used for the compressive tests. The two halves of each briquette are crushed separately, and the sum of the two results divided by the total area of the briquette, thus obtaining the compressive strength per unit of surface. The surface area of the United States standard briquette recommended by our Committee is almost exactly 4 sq. ins. Instead of the halves of a briquette, a single cylinder having the same thickness and the same area of surface as a whole briquette may be used with substantially equivalent results.

Specimens which are rough or uneven may be smoothed by gentle rubbing with the hand on a stationary grindstone.

In breaking, the pressure should increase uniformly, and at such speed that it will require between one and two minutes to crush each specimen.

For comparing the strength of cement paste or mortar with that of other materials which cannot readily be moulded in cement moulds, the Commission recommends cubes having an area of 50 sq. cm. (7.75 sq. ins.) on each face. For a United States standard, cubes 2 ins. on an edge, that is, with all faces having an area of 4 sq. ins., conform to most common usage, and are therefore best for this class of comparative tests.

Bending Strength.—The report on bending was made to the Commission by M. Durand-Claye.

The Commission adopted for this test square prisms 12 cm. (4.72 ins.) long by 2 cm. (0.79 in.) on a side. In breaking, a prism is placed on its side—that is, on a face which has been in contact with the mould—upon two knife-edges, 10 cm. (3.94 ins.) apart, and the load is applied at the center through a slightly rounded knife-edge. The load should be applied continuously at the rate of 1 kgr. (2.2 lbs.) per second. The same number of specimens should be broken as in tensile tests, and the results averaged.

M. Durand-Claye uses, for obtaining the fiber stress, the common formula:

$$R = \frac{3\,F\,l}{2\,b\,h^2} \qquad (1)$$

where F represents the breaking load, l the distance between supports, and $b\,h$ the section of the specimen.

For the section of 2 cm. square, this equation becomes

R' (in kilograms per square centimeter) $= 1.875\,F$ (in kilograms) ..... (2)

English measure will naturally change the dimensions of the specimen to 1 x 1 x 6 ins., to be broken upon knife-edges 5 ins. apart. Using the above formula for this section Mr. Thompson.

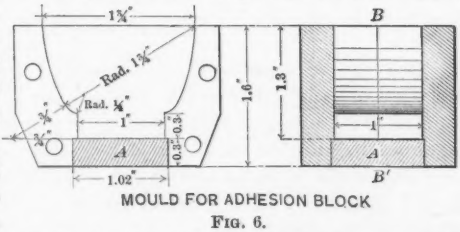
$$R'' \text{ (in pounds per square inch)} = 7.5\ F \text{ (in pounds)} \ldots\ldots\ldots (3)$$

Adhesive Strength.—The report on tests of adhesion was made by M. E. Candlot.

Adhesion is considered in two ways: First, with reference to the relative adhesive qualities of different cements; and, second, with reference to the adhesion of the same cement mortar to other materials of different natures. The same general method is advocated in both cases.

Briquettes are formed as described below, of a shape which can be broken in an ordinary tensile testing machine. The European tensile briquette is of small section, 5 sq. cm. (0.775 sq. in.), and of an inconvenient shape for moulding in halves. The area of the breaking section is therefore doubled by the Commission, while the curves where the clips take hold remain the same, so that the distance between the two points of each clip is unchanged. The shape of the United States standard briquette is such that fewer changes have to be made in its outline, and the regular section of 1 sq. in. need not be altered.

The Commission found that adhesion briquettes could not be moulded satisfactorily in the manner used for tension briquettes. They advised finally a mould in which a half briquette could be made, and then when this had set, the same mould could be used for completing the other half. In Fig. 6 is shown the style of mould selected, but with the dimensions changed to adapt the briquette to the United States standard form of clip. It consists of a bottomless box, which divides vertically in the center on the line, BB, so that the half briquette can be removed readily. The bottom is formed of a movable bronze plate, shown at A.



MOULD FOR ADHESION BLOCK

FIG. 6.

For the first class of tests, to determine the relative adhesion of different cements, a normal adhesion block is formed of a mortar composed, by weight, of 1 part of highest quality Portland cement, which has passed a No. 75 sieve, and 2 parts of fine sand, gauged with 9% of water. As soon as it is rammed into the mould, the mould is removed, and after remaining in moist air for 24 hours the half briquette is placed in water until it is required. It must set for at least 28 days. When required for use the block is dried, and the surface polished with emery paper. The block is then placed on a table with the large end down, the half mould, with the disc A removed, set on top of it

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and filled with plastic mortar consisting of the cement which it is desired to test mixed with sand in the required proportions, thus completing the briquette. This briquette is treated and tested as an ordinary tension specimen.

For the second class of tests, if the material can be moulded, it is formed as a half briquette, and the specimen completed with the mortar to be tested. If solid, a plate of the material, several millimeters thick, having one smooth face, is prepared, and placed at the bottom of the mould, on top of the bronze plate, and the first half of the specimen is formed by filling the mould with neat cement. After setting, the half of the briquette is completed with the mortar which it is desired to test.

Porosity Tests.—The report to the Commission on methods of measuring the porosity of mortars was made by MM. P. Alexandre, P. Debray, and H. Le Chatelier. The recommendations of the Commission are almost identical with this report.

The porosity of a mortar is expressed as the ratio or percentage of voids to the total volume. In measuring the voids all water in the mortar is included except that of crystallization.

If

V = total apparent volume of mortar;
v = volume of solid portion of mortar;
v' = volume of voids in mortar;

then

$$\text{Porosity} = \frac{v'}{V} = \frac{V-v}{V}.$$

The size of specimen recommended is that having a volume of between 0.3 and 0.5 liter (18 to 30 cu. ins.).

The solid volume, v, is found by the application of the principle of Archimedes, that the difference between the weight of a body in air and its weight when suspended in a liquid is equal to the weight of the liquid displaced. From the weight of the displaced liquid, its volume, which is manifestly the volume, v, of the mortar, can be calculated readily.

In English measure, if

P = weight of specimen after drying;
p = weight suspended in water after saturation;
W = weight of 1 cu. ft. of water;
v = volume of solid portion of mortar;

then

$$v \text{ (in cubic feet)} = \frac{P-p}{W}$$

In order that the specimen may be thoroughly impregnated with water and all air driven from the pores when determining p, its weight in water, the specimen is first exposed for ¼ hour in rarefied air at a pressure not greater than 25 mm. of mercury. Water is made to cover

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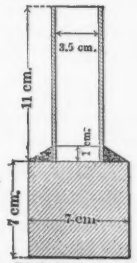
it, and then the atmospheric pressure is restored. It must now remain in the water 24 hours before being weighed. If apparatus for rarefying the air is not at hand, and if the specimen will stand exposure to heat, an alternate method may be used. The specimen, after 48 hours in water, is placed in cold water, raised to boiling, and boiled for 2 hours, then allowed to cool for 24 hours. The weight, P, used in this determination, is taken after exposing it to a heat of between 40 and 60° Cent., until there is no loss in weight, care being taken to prevent any access of carbonic acid gas from the heating apparatus.

The apparent volume, V, of the specimen, can be found by direct measurement, or by calculation from its loss of weight in water, using again the principle of Archimedes. To prevent saturation in the latter proceeding, it can be covered with a thin coating of grease spread with the fingers. The weight in water must be taken before that in air.

The standard test of porosity is made with 1:3 mortars of normal plastic consistency, 28 days old. Other proportions and ages suggested are 1:2, and 1:5, at 7 days, 28 days, 6 months and 1 year.

Permeability Tests.—The Commission decided to use for this test a solid cube of mortar in preference to a hollow cylinder.

The permeability of neat cement and mortars is expressed by the number of liters of water passed in one hour through a cubical block, 50 sq. cm. (7.75 sq. ins.) on a face, the size used for compressive tests. A glass tube, 3.5 cm. (1.38 ins.) in diameter, and 11 cm. (4.33 ins.) high, is sealed vertically by means of neat cement to the uppermost face, carefully cleaned, of the block which has been placed on its side, that is, against a face which has been next to the mould. This is shown in Fig. 7. For varying the pressure, a rubber pipe is attached to this tube, and its upper end connected with a reservoir. The height of pressure, according to the permeability of the mortar, may be 10 cm., 1 m. or 10 m.



FRENCH TEST FOR PERMEABILITY

FIG. 7.

Before taking the test, the block is immersed in water for 48 hours, and remains in water during the test. The periods recommended are: 24 hours, 7 days, 28 days, 3 months, etc. The standard test is made at 28 days. Tests are made on three blocks, and the average taken of the two which are most concordant.

Logically, we should suggest for the block to be used for testing permeability in this country, the size mentioned for compression, that is, a 2-in. cube. Further investigation is considered necessary, however, before adopting either the size or shape as a standard.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

TIMBER TESTS.

An Informal Discussion at the Annual Convention, June 10th, 1903.*

SUBJECT FOR DISCUSSION:

"TIMBER TESTS."

BY MESSRS. W. K. HATT, H. VON SCHRENK, GAETANO LANZA, A. L. JOHNSON AND S. BENT RUSSELL.

Mr. Hatt.

W. K. HATT, Assoc. M. Am. Soc. C. E.—The speaker, who is on the staff of the Bureau of Forestry in the work of organizing the projected investigation of the strength of timber, has been asked to represent the Bureau of Forestry in this discussion. A general statement of the character of the investigation has been prepared by Gifford Pinchot, Assoc. Am. Soc. C. E., Forester, which is here reproduced as published in the *Proceedings*† for April, 1903.

"The Bureau of Forestry, of the United States Department of Agriculture, intends to resume the work of testing timber formerly carried on by the Division of Forestry during the years 1891–1896. A large portion of the groundwork covered by the proposed investigation is of interest to engineers, and it is the desire of the Bureau that the results obtained shall be of the greatest value to them. To this end it is

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV, p. 71.)

Communications on this subject received prior to September 25th, 1903, will be published subsequently.

† *Proceedings*, Am. Soc. C. E., Vol. XXIX, April, 1903, p. 133.

hoped that those engineers interested in the application of timber to construction, will, in this discussion, offer suggestions and make criticisms which will aid the Bureau in planning this series of tests. Mr. Hatt.

"It is the intention of the Bureau to take up these tests in a thorough manner, and devote whatever time may be necessary for the solution of the problems involved. It is expected that the plan of operation will be sufficiently complete, and the methods of tests so well chosen, that the data obtained may be accepted by all experts.

"The following account of the proposed tests is of a very general nature. Those who are particularly interested can obtain a description of the proposed tests in greater detail on application to the Bureau of Forestry, Washington, D. C.

"The Bureau aims at results of practical value, such as the values expressing the strength and stiffness of the principal merchantable species of timber of this country. Not only will this be done for timber now in use, but efforts will be directed to ascertaining the value for structural purposes of timbers at present not largely used, as, for example, the Western Hemlock and the Southern Gums. A thorough series of tests will be made of the timbers of the Pacific Slope, particularly the Red Fir, otherwise called Oregon Pine or Douglas Spruce, which is now finding its way in increasing quantities to eastern markets. If it should appear that the work done on the Southern Pines by the Division of Forestry during the years 1891–1896 has been sufficiently complete, the proposed tests will not cover these timbers.

"Experimentation will be directed also in advance to the investigation of the effects of different factors of the testing processes on the results, such as speed of application of a load, method of moisture determination, the effect of moisture, and of volatile oils.

"The investigation of the effect of technological operations, such as methods of kiln drying, methods of preserving timber, etc., will be undertaken.

"In determining the values of the strength and stiffness of various merchantable timbers, tests will be made, both on timber collected from the market and on timber collected in the forest. Full-sized sticks, as used in construction, will in all cases be tested under their appropriate loadings.

"Work is at present in progress at a station in California, on the different merchantable grades of these full-sized timbers, such as bridge stringers and car sills collected on the market. The locality of origin of the timbers is determined, and a full description of each stick, as well as a series of photographs of all six sides, is made a matter of record. Full information of the physical and mechanical properties of the sticks under test will be obtained.

"The investigation of the effect of various conditions of forest growth on the physical and mechanical properties of timber will be undertaken whenever the Bureau is thoroughly prepared for this work.

"It is hoped that the discussion will take up the need of making timber tests from the standpoint of the engineer. Suggestions are invited as to those particular matters which at present most need investigation. It is also desired that discussion shall take place concerning the methods of performing the tests, particularly as to the best method of determining the moisture in timber; and the best method of determining the shearing strength of timber.

"It is hoped that a full criticism of the former tests, both as to methods and content, will be given.

Mr. Hatt. "It is recognized that timber is subject to a great number of variables. From the botanical standpoint, the ideal method of procedure would be to determine the properties of the wood fiber of each species representing the normal growth of straight-grained timber. With these standard values as a basis, inquiries could be directed to ascertain how much the values are affected by such variables as moisture, oil, speed of test, imperfection of structure due to direction of grain, or knots, rate of growth, diseases of the tree, technological processes, such as kiln drying or preserving, etc.; forest conditions, region and growth. It would seem that the interests of all, whether engineers, manufacturers, or botanists, would be consulted by such a method of procedure. The particular series of tests on full-sized sticks of market timber would form part of this general scheme."

The Bureau has sent out a preliminary circular, to many engineers and others interested in the utilization of timber, in order to determine the need of future tests and to formulate a plan of procedure. After the content of the investigation and general plan is determined in its general features, by such correspondence and preliminary discussion, it is the intention to perfect the arrangement and details of this plan, involving methods of measurement and experiment, and submit it to experts for a record of agreement or disagreement with the proposed methods of test. The plan and methods, as far as practicable, will be of such a character that the work may be undertaken in part, and the partial results obtained will be of use throughout the entire investigation.

The results of the preliminary canvass of those interested in the utilization of timber will be published in due time. The replies to the circular make evident the fact that, far from the belief that the problems connected with timber are not serious because of a partial and growing replacement of timber by other material, there is a lively appreciation of the importance of a continuous organized study of methods which will economize the use of timber, lengthen its life, and develop the supply by proper forestation. The matter of determining the strength values of timber is only a minor part of the general need. In view of the variability of the product, the details of testing operations are considered by many to be of minor importance.

Such useful lines of work as the following have been suggested :

The need of proper determination of the strength of the Pacific Coast woods, Fir, Spruce, Hemlock, and the Eastern Spruce and Hemlock, which will form the future supply of structural timber, is suggested from many quarters. The determination of the mechanical properties of the various hardwoods which probably will form substitutes for the Hickory and White Oak in carriage construction is a matter of importance.

The majority of engineers would be more satisfied with the results of tests of the timber actually supplied to the market by saw-mills

(timber of prime quality, average quality, merchantable, square-edged, etc., as modified by the forms and proportions of sticks and by various degrees of seasoning), than by tests conducted on timber collected from the forest and sawed up at the order of the engineer of tests, in order to obtain a solution of the various problems which confront the forester and the botanist. One prominent user of timber insists that the quotation of the strength of timbers should be made with reference to the sizes and lengths of sticks, as in his experience the unit values to be used in design should be much smaller as the sticks become larger. The degree to which the values obtained from tests on new material are to be reduced by the inevitable decay which results from their use, is another matter which has been suggested. Mr Hatt.

The need also is pointed out of uniform standard rules of inspection and grading, involving the determination of the value of the reducing factors due to knots, crooked grain, and sap. A useful work is suggested in the presentation of photographs, etc., of the appearance of sawed lumber of different species.

Shippers demand a determination of the average weight of different species of timber, at different degrees of seasoning, as a basis for the computation of freight charges.

All unite in the expression of the usefulness of an investigation of the proper methods of preserving timber and the most advantageous species to be used in cases where the timber is to be preserved. Questions of the relative life of treated lumber to be expected under different exposures, and the question of the strength of such treated lumber, are also matters of importance to many. The proper methods of seasoning, or hastening the seasoning process, of both hard and soft woods, is a matter which might be investigated with great profit.

From the standpoint of the forester, the effect of the more important forest conditions upon the strength of timber is of scientific and practical interest. Such problems as the relative strength of swamp and highland hardwoods, first- and second-growth timbers, etc., suggest themselves; and a demonstration of the appropriate uses of these inferior timbers, which at present are left uncut in the forest, and which improperly influence the future character of the forest, will be of use to the forester.

It is evident that the subject of timber investigation is a formidable problem to attack. The ideal procedure would involve a systematic programme in advance, including all the problems, so that one part of the field may be covered at one time and the results afterward may fit the general scheme. This plan, of course, would involve testing timber as found in the forest, in which all the conditions are known. And yet, while this is true, the speaker agrees with those who believe that the most direct method of getting unit strength values for the engineer is to test timbers in actual sizes as found on

Mr. Hatt. the market. There is some waste of time and duplication of work in this manner of procedure, from the standpoint of the complete investigation of all problems, but the usefulness of the results to the parties for whom the tests are designed, will practically be much greater than by any other method. The progress of knowledge derived from experiment will thus take place in the same manner as in the case of other materials. In no case has the entire subject been cleared up in a single investigation, however ideal that procedure would be. In all cases care should be taken to determine the species of timber under test, and to ascertain the region of growth. There is no difficulty in determining the species, and region of growth from the records of the lumber dealer, in the case of large timbers. The weight, rate of growth (as shown by annual rings), and the defects, can be made a matter of record. A complete study of species, from the botanist's standpoint, would involve the detailed examination of the entire tree as cut in the forest.

The following discussion aims at a summing up of the recent additions to our knowledge of the mechanical properties of timber, and the consideration of the directions in which further experimentation should be made, both to determine mechanical properties as affected by different conditions and to improve methods of preserving timber and of technological processes. The discussion does not concern itself with details of methods of test and measurement. Propositions in regard to these details will be presented to the American Society for Testing Materials, at the meeting at Delaware Water Gap, on July 1st to 4th, 1903. Nor are dendro-chemical problems mentioned.

Recent Additions to Knowledge.

The strength of the different species of timber of the United States, used in construction, as known up to the year 1895, is very well summarized in the Report of a Committee of the American International Association of Railway Superintendents of Bridges and Buildings, presented before the Convention at New Orleans, on October 16th, 1895. This report presents the results of an exhaustive compilation by Walter G. Berg, M. Am. Soc. C. E., Chief Engineer of the Lehigh Valley Railroad. The values obtained by different experimenters are listed in a number of tables. This report is reproduced in Bulletin No. 12 of the Division of Forestry, United States Department of Agriculture. A more complete table of mechanical properties of a wider range of species is contained in the Report of the Tenth United States Census. A summary of the results accomplished in the former United States Government Timber Tests will be found in "The Materials of Construction," by the late J. B. Johnson, M. Am. Soc. C. E., both as to moduli of strength and effect of various factors.

This summary is more complete than any given in the interrupted official publications of the Division of Forestry. Mr. Hatt.

Since 1895 the experiments worthy of note are those on White Pine, Red Pine, Hemlock and Spruce by Professor H. T. Bovey, of McGill University,* showing that in many cases no increase of strength can be counted upon due to the reduction of the moisture from a green to a kiln-dried state, in the case of large beams. This contradiction of the indications from tests on small sticks is due to the checking of the beam during drying, and subsequent failure under longitudinal shear.

Additional information concerning the mechanical properties of species is contained in Circular No. 19 of the Division of Forestry, United States Department of Agriculture, dealing with the strength of Bald Cypress.

William Hood, M. Am. Soc. C. E., Chief Engineer of the Southern Pacific Railway, has made an extensive series of tests of full-sized sticks of the Red Fir, with a view to obtaining unit values for timbers of different sizes, and the effect of creosoting on the strength. He finds that both the modulus of elasticity and the fiber stresses must be diminished with increasing depth of beam. Thus, for a depth of 2 ins., the modulus of elasticity is 1 793 000 lbs. per square inch, the elastic limit is 6 950 lbs. per square inch, and the modulus of rupture is 11 200 lbs. per square inch; whereas, for a depth of beam of 16 ins., these values, as figured from the load at first indication of failure, are 1 074 000, 3 769 and 5 590 lbs. per square inch, respectively. In Mr. Hood's tests, however, the reduced values for larger sticks are due to the effect of the relatively short span in bringing about failure under longitudinal shear. There is no decided indication of actual diminution of fiber strength at the center. However, the practical use of beams in the ratios of span to depth equal to those used under test conditions, make the results reached by Mr. Hood of significance in determining the ratio of depth to span at which the beams must be designed for longitudinal shear. He finds in the case of 8 x 10-in. creosoted Red Fir beams, that the modulus of elasticity, the elastic limit and the modulus of rupture are 0.973, 0.826, and 0.606, respectively, on the basis of unity as the value for untreated timber. The reduced strength is mainly to be accounted for by the presence of checks arising from the creosoting process, and from the diminution of the shearing strength of the wood. These influences determine a diminution of the strength of the large beams compared with similar large beams.

L. E. Hunt, Assoc. M. Am. Soc. C. E., of the University of California, has demonstrated the diminution of shearing strength of creosoted Red Fir timber. He finds that the other quantities, elastic limit,

* *Transactions*, Canadian Society of Civil Engineers, Vol. XIV, 1897.

Mr. Hatt. modulus of elasticity, etc., are but little affected. These same statements apply to Burnettized timber.

A valuable series of tests on full-sized timbers and structural details has been in progress at the Laboratory of the Massachusetts Institute of Technology, under the direction of Professor G. Lanza, with a view to obtaining unit stresses appropriate to market timbers.

A series of tests of Redwood and Red Fir, from sticks of 4 x 4 ins. in cross-section, has been made under the direction of Professor Soulé, of the University of California.

A comparison of the mechanical properties of the Red Fir and Southern Yellow Pine, as based on sticks 4 x 4 ins. in cross-section, has been made at the Bremerton Naval Station by Naval Constructor Frank W. Hibbs, showing that these two woods are about equal in value, as far as the mechanical properties are concerned.

In general, it may be said that our present knowledge of the average mechanical properties of the different species of structural timber is fairly complete, as far as such values may be based on small sticks. The reductions which must be made in case of large timbers of the different merchantable grades, and the manner in which these values are affected by forest conditions, are largely unknown. The effect of moisture on the mechanical properties of wood fiber has been well determined, but the proper reducing factors for the effect of moisture, in case of large sticks, are not known. Nor are the moisture contents of market timber well known. It is fairly well established that, in woods of uniform structure, the strength increases with specific weight. The relations between the mechanical properties of any one species are only partially established. The variations of the physical and mechanical properties with position in trunk are well established in the case of the Southern Pines.

The outline of any future work should not duplicate work already performed in a reasonably satisfactory manner. Tests should be confined to species that give promise of being on the market for some time. Before presenting an outline of the series upon which investigations may profitably be made, some discussion will follow on the various factors which enter into the problem.

Technological Processes.

Kiln Drying.—The effect of hot-air drying on the strength was investigated in the former United States timber tests. It was found that, for any temperature commonly used in drying lumber, no detrimental effect on the strength would be produced, aside from the checking action which might result from too rapid drying of the exterior portion of the stick. The effect of very high temperatures and pressures used in drying, as in the vulcanizing process, is, according to the former Government timber tests, to reduce the strength slightly.

Mr. Hatt.

The subject has not been well covered, and an investigation of the temperature and rate of drying, to determine the best conditions for the prevention of checking, together with a general study of the methods of seasoning, is planned. This, however, is outside the realm of mechanical tests, as is a projected study of the behavior of timber in the operations of steaming and bending.

Bleeding for Turpentine.—The effect of bleeding Long-Leaf Pine for turpentine is not detrimental to the strength of the timber, according to the results of the previous Government mechanical and chemical tests. These tests are believed to be conclusive, and will not again be taken up, except to determine the effect of this operation on the durability of the timber.

Fire-Proofing.—Other matters which are to be taken up in the proposed investigation include a study of the effects of fire retardants, and their efficiency for various species of timber, as well as the effect of these on the mechanical properties, and on nails and fastenings.

Preservatives.—A study of the durability of the different woods in their natural state under ordinary service conditions will be useful in giving information as to what species of wood are suitable for given conditions. A large field for investigation is the efficiency of preservatives in the treatment of the so-called inferior woods, such as second-growth Loblolly Pine, Hemlock, Red Oak, Beech, Eucalyptus and the Gums. This most valuable study will be outlined after consultation with those at present studying the subject. It is desirable that laboratory tests be devised to avoid the excessive cost of field tests.

Variations in Quality, and Imperfections.

It is the common belief that tests on small sticks do not yield unit values applicable to large sticks. It is supposed that the small pieces selected for test are unavoidably of a better average character than large sticks; very often these small pieces are clear and straight-grained. Experimental evidence seems to show that the results of tests by those who test large sticks are lower than the results obtained by those who have experimented on smaller sections.

It seems reasonable to suppose that the modulus of elasticity and the elastic strength of identical material should not be affected by the size of the specimen, provided that the ratio of depth of beam to span be great enough to eliminate largely the effect of shear. It is known, however, that two pieces of wood are far from identical. In spite of this heterogeneous character of timber, however, small and large sticks may yield equal moduli, for the reason that the effect of a knot of given size is more serious in a small stick than in a large stick. And this consideration may explain the fact that, although timber in small sizes is usually more free from knots and other defects than timber of large sizes, the comparison of results of tests of a large stick

Mr. Hatt. with a number of tests on small sticks cut from this same large stick shows that there is no significant difference in the average unit values from the large and small sticks. This is what the former Government timber tests have shown.

What the designer wishes to know, however, is the most probable strength of the different sizes of timber and different grades of timber that he is compelled to purchase on the market, as, for instance, the different grades of car sills, stringers, and carriage material. It seems to the speaker that this knowledge can only be reached through a direct test of the actual market timbers, the qualities of which are determined by the saw-mill. A given log is cut in such a way as to furnish the desired products to the best advantage. It is less likely that logs sawed up under the direction of the engineer of tests will yield results comparable with these commercial products, which represent the combined judgment of a great number of engineers and lumbermen. The relation of the strength of large sticks to the small sticks cut from them does not necessarily agree, for instance, with the relation of the quality of a railway stringer and car sill, both of first-grade merchantable timber, cut from a given log.

Useful information will be presented by the proposed method of photographing the sticks tested, so that the effect of different kinds of knots. and the position of these, upon the strength of the different kinds of test pieces may be determined by the individual who examines the reports. In the publication of results of tests, analyses should be presented to determine in some quantitative measure the reduction of the moduli due to the effects of knots, shakes, and crooked grain. Information will also be available concerning the liability of various species to these defects. The former Government publications relating to timber tests have been criticized because no record was made of the quality of the sticks. This criticism will be met in the future by the publication of photographs of the sticks, showing the grain and defects and a quotation of the market grade of the stick. Tests are now under operation, and will be continued, on sticks of various sizes and grades, as purchased on the market.

Forest Conditions.

The influence on the quality of timber of the various forest conditions, such as climate, winds, rain, seasonal variations, soil, elevation, rate of growth, density of stand, time of cutting, position in tree, etc., is of interest, and the determination of the effect of the more important of these should be included in any extended study of timber, to the end that in forest management or in reforestation the best results may be obtained, or that present prejudices may be removed. This formidable investigation has scarcely been entered upon in a formal

way, although a large body of information is in existence as the result of experience and observation. Mr. Hatt.

No useful results have as yet attended the attempts to solve many of these problems, by European investigations, or by the former Government Timber Tests. Many of the factors seem to be of such minor importance that their influence is necessarily obscured by the inevitable differences in test pieces obtained under apparently identical conditions. It also seems impracticable to obtain any modulus which will represent the mechanical properties of a tree grown under given conditions. Knowledge of the effect of forest conditions, in the speaker's opinion, must be largely inferential, and not precise. A practical method of obtaining these relations would involve, first, a determination of the mechanical qualities of timber of various grain and weight; the forester or botanist can then, by an inspection of the wood under examination, in the forest, decide its value by reference to the tables prepared for him as a result of previous mechanical tests. This, however, is only the speaker's personal view.

One useful outcome of this investigation might be the determination of the most favorable condition for the production of any given species, as to the various conditions, such as soil, density of growth, elevation, climate and seasonal changes. It is possible, however, that this matter is not of immediate practical importance, because in the United States, for many years to come, trees must grow under conditions little changed from those of the present. Useful conclusions can be reached in pointing out the relative value of timber grown in different regions of the country, as, for instance, the relative strength of Northern and Southern Hickory, of first- and second-growth hardwoods, of Coast and Mountain Red Fir, of first- and second-growth Loblolly. The timber as found in the market, with its important features of weight and rate of growth known, will serve this purpose in general.

The tests on inferior species are of great importance, because they will undoubtedly tend toward a greater utilization of the inferior woods. If these inferior species can be cut and marketed at a profit, it would be a great help to the future sylvacultural condition of the forest itself. As it is now, usually only the most valuable species are cut, leaving the inferior ones. As a result of this, the future forest is composed largely of the poorer class of trees. If these inferior species can be largely cut, and a small percentage of the valuable species left standing, the chances are much better that the new growth will contain a large percentage of the valuable woods. The Bureau has not yet planned a formal investigation of the effect of forest conditions, and does not contemplate taking this up until more pressing matters are disposed of.

The matter of supplementing the former Government timber tests

Mr. Hatt. by tests on inferior woods, in order to determine strength moduli, is also important, for the reason that some of these inferior woods have replaced the better grades, and will continue to do so at an increasing rate on account of the increasing price of the latter. For instance, architects are now using, for indoor service, 8 x 16-in., square-edged timbers, of second-growth, Loblolly Pine, of almost entirely sapwood, of such rapid growth that four annual rings occur in 3 ins. at a point more than half way between the heart and the outside of the stick. It is evident that the results of tests on first-growth merchantable Pine of the best grade will not apply to such material as this.

Joints and Frames.—Tests to determine the strength of structural details, such as joints and frames, may be left to private enterprise.

Variations in Testing Process.

Rate of Loading.—At present it is known that the rate of application of the load exercises a very important influence upon the shape of the load-deflection diagram, particularly at the loads just preceding rupture. It is known, also, that the deflections under the ordinary quickly-applied load in a test are only one-half of those resulting from the continued application of the same load. The quantitative relations are not well determined, and a further study is imperative, and has been planned.

Moisture.—The method of determining the moisture contents of the sticks under test, and the use to be made of such moisture determinations in reducing the moduli to a common basis of moisture, are matters that excite a great deal of discussion on the part of operators of tests. A series of tests should be made, to determine the proper reducing factors in the case of large timbers, as between the green and dried states. While the results of tests on small-sized specimens show that the strength of dry timber is nearly twice that of green timber, it is probable that in many cases no such increase is to be expected, on account of the diminution of the shearing strength due to the checking action arising during the drying-out process. An investigation will be made to determine the relation between the different methods of determining moisture in wood, and the disturbance of results due to the presence of volatile oils in the material under examination. At present it appears that the latter is of minor importance.

The Bureau will, in general, test material in a green state, and for this purpose it will be necessary in some cases to bring the sticks artificially to the degree of moisture corresponding to the green state. A sufficient number of sticks will also be tested, after a thorough drying out, to determine the relation between the values in the green state and in the dry state. This information, together with the knowledge of the scientific law governing the relation between moisture and

strength, unaffected by defects of checking or unequal moisture distribution in beams, will be sufficient to enable the designer to decide upon the reducing factors appropriate to the conditions of service under which the timber is to be used. This condition of service involves, usually, either entirely dry timber or timber approximately green. Mr. Hatt.

In all cases, however, the moisture content of the timber will be determined by cutting out discs, about 1 in. thick, from the section of the beam near rupture, and at one of the quarter points, and drying these discs in an oven at a temperature of 100° Fahr. Although this exposure does not determine the entire moisture in a disc, the percentage remaining is less than the error of observation, and the method will determine the necessary empirical reducing factors. It has the further merit that the degree of seasoning of any particular timber can be easily determined by any engineer. A study of the merit of a kiln temperature of 80° is under way. This temperature avoids a disturbance of results due to melting of resin, oxidation, etc. Information will also be procured as to the degree of seasoning to be expected in timber as found on the market. A great deal of timber sold as air-dried in the yards is only dry on the surface, and is practically green in the interior portions.

Species to be Tested.

The species to be tested for mechanical properties should include timber at present in use for which unit values for design are needed, and also timbers which, though available, are not at present in extended use. Of the former, the following species may be noted: Western Red Fir, Hemlock, Spruce; Eastern Spruce, Hemlock and Fir. The western forests will form future supply grounds for the greater part of the timber that will be used in construction. The Red Fir, otherwise called Douglas Spruce or Oregon Pine, has been tested to some extent, both in the former Government tests and by William Hood, Professor H. T. Bovey, Professor C. B. Wing, and Professor Frank Soulé. The Western Hemlock is cut to a large extent and sold on the market as Fir. Both the Hemlock and Spruce are used in filling orders for second-grade Red Fir. The Western Hemlock is a very good timber for constructional purposes, and is also used in inside finishing. It does not shake or splinter. It also possesses immunity against the attacks of insects. It suffers in public estimation from the reputation of the Eastern Hemlock. It grows very rapidly, and may be counted upon to reforest cut-over lands. It has been found of a diameter of 8 ft. and a height of 250 ft. As a rule, the mature trees are from 3 to 5 ft. in diameter, breast high. The Western Spruce is also found in trees of large sizes, and shares with Hemlock an important role in future timber supplies. Considerable

Mr. Hatt. supplies of Eastern Spruce, Hemlock and Fir are yet to be found in Pennsylvania and New York, and furnish constructional material for many purposes in the Northeastern States. A series of tests will be made with large-sized sticks of Southern Pine, to add to the rather meager tests on large-sized Southern Pine sticks, and on the poorer grades of these.

Of the timbers not at present in use for structural purposes, there are large supplies of Southern Red Gum which will furnish timbers of sizes used in building construction. After the better material for flooring, wagon stock, etc., has been sawed, the heart cull will furnish valuable joists. It is proposed, by a series of tests, to determine the quality of these, as well as the properties of the better parts of the log.

Other timbers suitable for rapid growth under extreme conditions of wet and dry sites, as Catalpa and Eucalyptus trees, which are being planted very largely throughout the West and Southwest, should be studied. In Australia the Eucalyptus is one of the most important sources of timber supply for building ships, bridges, agricultural implements, etc.* The Tamarack is a tree suitable for growth in wet situations.

These studies should be on trees from the forest as well as on market timber.

Number of Tests to be Made, and Sizes to Test.

The number of tests depends on the uniformity in the timber of each species and upon the end in view. If it is desired to obtain the strength values for merchantable timber, it would be probably necessary to test, say thirty sticks of each particular size of each special grade; thus thirty stringers of first-class merchantable Red Fir would be tested, and the same number of second-grade merchantable; twenty select stringers and twenty clear stringers. This should be repeated in the case of three or four markets.

If it is desired to study the effect of forest conditions on the strength of the fiber of a definite part of a tree, or the effect of variations in the testing process, the timber selected should contain as few variables as possible, and the number of tests would naturally be arranged to correspond with the quality of timber obtainable. In case of these scientific tests, in which the sizes must be chosen so as to eliminate, as far as possible, other variables than the one under examination, it will be necessary to use sizes of timber 3 x 3 ins. in cross-section, or thereabouts.

In case of tests for the purpose of obtaining unit values, actual sizes should in all cases be tested, as, for instance, car-sill sizes, stringer sizes, roof-truss sizes, carriage stock, columns, floor beams,

* Forestry Bulletin No. 35, page 35.

etc. The appropriate sizes would be quite different in the cases of Red Fir and Hickory.

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Quantities and Properties to be Determined.

Some or all of the following properties will be measured, as is appropriate to the use of the species:

Mechanical properties of species.

1.—Strength,
2.—Stiffness,
3.—Resilience,
4.—Hardness,
5.—Brittleness,
6.—Penetration of definite-sized punch,
7.—Abrasive qualities,
8.—Turning qualities,
9.—Weight per cubic foot.

Physical properties.

1.—Shrinkage and swelling and absorptiveness,
2.—Identification by structure,
3.—Identification by appearance of sawed lumber.

The foregoing mechanical and physical properties have partly been determined in the former timber tests. The properties of brittleness and penetration under pressure will be investigated by proper tests. The abrasive qualities have a bearing on the use of wood for paving blocks. In many cases the turning qualities, under a tool in the lathe, must be known. Under the physical properties, the shrinkage is important, from the point of view of the manufacturer. Engineers would be glad to be able to determine the species of sawed timber from its appearance in the lumber yard.

There is at present no standard table of weights of lumber for use in settling disputes between manufacturers and transportation companies, and an endeavor to formulate such a table will be made.

Kinds of Tests.

The kinds of tests to be made in determining these properties cited will include a part or all of the following:

Bending.—

Fiber stress at elastic limit,
Modulus of rupture,
Modulus of elasticity,
Modulus of elastic resilience,
Modulus of ultimate resilience,
Maximum horizontal shearing stress.

Mr. Hatt. *Crushing.*—

End of grain; strength, modulus of elasticity,
Side of grain; yield point.

Shearing.—

Radial, transverse.

Torsion.—

Column Tests.—

Hardness.—

By the width of scratch made by a prescribed tool under a prescribed pressure,
By the width of indentation of a prescribed steel cylinder.

Abrasive Qualities.—

By Dorrey abrasion machine, in which the wood is ground by an abrasive powder.

Turning Qualities.—

A piece is put in the lathe and the result photographed.

Brittleness.—

Test beams, under impact tests, 3 x 3 x 36 ins., in size.
Test prisms, under compressional impact, 3 x 3 x 36 ins., size.

Shrinkage.—

Specimen, about 3 x 2 x 12 ins., with sides parallel to radial and transverse direction.

The details of tests which are more interesting to experts in the technique of testing operations, will be presented for discussion before the American Society for Testing Materials at the meeting at Delaware Water Gap, July 1st to 4th, 1903. Some general considerations may be mentioned here.

Methods of Making Shearing Tests.—Various methods of determining the shearing strength have been used. The difficulty is to obtain a pure shear unaccompanied by splitting of the test piece due to bending. This difficulty is often met in case of double shear under tension test. The test piece and method of test are more simple in compression than in tension. Compression tests, apparently, can only be applied properly for the determination of single shear. The latter is more satisfactory, in that the failure occurs on only one surface, and the exact stress may be determined. The shearing tests will be made in compression in single shear. The values obtained by shearing tests on small pieces should be modified by the results of the tests on large beams, for which the shearing stress at the neutral axis should be calculated.

Method of Loading.—The measurement for deflections is most simple when the load is applied at the center of a beam. On the other hand, a larger portion of the stick is brought under the maxi-

mum stress when the load is applied at two points. In the latter case, a longer beam is necessary, in order to yield the proper ratio between depth and span. In the speaker's opinion, the simplest method is to apply the load in the center and compute the bending moment at the point of failure. The loads are to be applied continuously at a fixed speed. Mr. Hatt.

Method of Making Cross-Crushing Tests.—The former Government tests were made on sticks of definite section, and the results give the loads which caused compressions of 3 and 15%, respectively. These results have little significance for other sizes of timber. The method planned will be to apply loads in increments across the stick, and measure the accompanying deflections of the piece, in order to determine the load at the yield point of the timber under this load. The tests will be supplemented by what may be termed penetration tests, in which the load required to bring about the penetration of a punch of given area to a given depth will be determined.

Method of Making Impact Tests.—In determining the relative brittleness of different timbers, the test pieces in compression and bending, both under transverse and actual loads, will be used. In case of compression tests, the test piece, 3 x 3 x 6 ins., will receive blows of increasing height, and the height of blow at which definite failure occurs will be noted. The indication of failure will be the wrinkling of the surface due to the initiation of a shear. In the bending test, the energy required to rupture a 3 x 3 x 36-in. stick will be measured, and also the height of blow required to produce a set of specified amount. These measurements will be made on a revolving drum which receives a record from a pencil attached to the hammer. A study of the resilience of hardwoods is planned.

Organization.

The organization of the timber tests presupposes a central laboratory at Washington, D. C., directed by the Bureau of Forestry, and other testing stations at such points as the Pacific Coast, the Mississippi Valley hardwood centers, and the North Atlantic region. These testing stations will be under the direction and inspection of the central laboratory, to which copies of all data taken will be sent. All tests will be made under uniform methods prescribed in advance. At each testing station there will be a resident engineer with proper assistants to carry on the work. The timber for tests will be selected by the engineer acting in conjunction with a dendrologist and an experienced inspector.

Publication.

In the publications, the results of tests on individual sticks will be quoted, in all cases, and the data presented in such a way that the user

Mr. Hatt. can determine the range of results from which averages are obtained. The data will be marshalled in the form of tables to suit the requirements of users.

Summary.

To summarize the work as planned at present, it may be said that the following series are under consideration, with a view to prosecution.

Tests to Determine Properties of Structural Timber.

Series I.—Tests of the Mechanical and Physical Properties of Timber, as Found on the Market.—Material will be of actual sizes and grades of commercial products. The purpose is to determine moduli for design; to determine the value of woods now considered inferior; to determine the liability to knots, and the reducing factors due to these; to arrange a table of standard weights, and rules of inspection and grading; partly to compare the properties of species from different regions.

Tests to Determine the Effects of Variations in the Testing Process.

Series II.—Effect of Rate of Application of Load, Including Impact tests.

Series III.—Effect of Moisture.

Studies of the Effect and Efficiency of Technological Processes.

Series IV.—Preservatives.

Series V.—Methods of Seasoning.

Series VI.—Fire Retardants.

For Future Disposal.

Series VII.—Effect of Forest Conditions.

Mr. von Schrenk. Hermann von Schrenk, Esq. (by letter).—With the increasing use of timber, preserved in one way or another against decay and fire, one of the most important problems which has arisen of late deals with the effect which the preserving process has upon the strength of the preserved timber. Many complaints have been made, and these seem to indicate that, for one reason or another, preserved timber has not the strength which the same material had before being treated with a preservative. This has been true, particularly, of creosoted timber. Many engineers believe, from actual experience, that creosoted timber is likely to be more brittle and less capable of withstanding strains than the same timber before being treated with creosote. This is particularly true with bridge timbers and piling.

It has been an exceedingly difficult matter to determine, without actual test, what relationship existed between the preservative proc-

ess and the supposed weakening of the timber. Most of the tests hitherto made with preserved timber have had little actual value. They were made, in the majority of cases, in the following way: Sticks of untreated timber were tested, and similar sticks of treated timber were likewise tested, and the results were compared. In many instances, these turned out in favor of the untreated timber. The reason why such tests are unfair to the preservative is that in the process of preservation, one deals not only with the actual process of impregnation with a preserving substance, but, also, in the majority of treating plants in the United States, with preliminary processes of steam-seasoning. It is very possible to steam a piece of timber, subsequently treated with creosote, to such an extent that the timber becomes exceedingly brittle. This, obviously, will be the fault of the steaming, and not of the creosote. The Bureau of Forestry, of the United States Department of Agriculture, is now planning a comprehensive series of tests to determine the strength of timbers used under various conditions, and one of the series of tests planned deals with the effect of preservatives on the strength and durability of timber. While it is not possible at this time to present a detailed plan for such a series of tests, it may not be without interest to the members of this Society to have a brief outline, presented for discussion at this time, as to what the writer believes ought to be some of the points to be taken into consideration in such a series of tests. Mr. von Schrenk.

Timber preservation, as stated above, may be divided broadly into three stages: First, the preliminary preparation; second, the actual preservative process; and third, the treatment of timber following preservation. In each of these stages the timber is subjected to treatment of one kind or another, and the final result, as to strength, is influenced materially by each of the stages.

Preliminary Preparation.

The preliminary preparation of timber for preservation must take into account the following factors:

1. *The Time At Which the Timber is Cut.*—The strength of timber differs materially, depending upon whether it is cut in winter, spring or summer. Any test, as to the influence of a preservative, should be made in such a way that the untreated and treated sticks are cut as nearly as possible at the same season of the year, so as to eliminate the seasonal factor.

2. *Seasoning.*—Before the actual preservative process, the timber is generally seasoned by one of several methods. The method commonly used in Europe is to air-season it. In some plants kiln-drying is resorted to. In the United States, most of the timber-treating plants use a process of steam-seasoning. Careful tests should take into account the influence, particularly of kiln- and steam-seasoning,

Mr. von Schrenk.

on preservation. One of the first series of tests in connection with timber preservation should relate to the influence of the following factors, in connection with steam-seasoning in particular. First, a test should be made to determine the influence of subjecting timber in the treating cylinder to steaming for various lengths of time with live steam. Second, a similar series should seek to determine the influence of steaming at various temperatures, and this will include steaming under pressure. Third, a similar series should determine the influence of steaming, for various lengths of time and for various temperatures, with superheated steam in closed coils.

The tests with steaming are considered of prime importance, because it is believed that much of the supposed weakening of timber by preservative processes is due to improper and excessive subjection of timber to live steam in the treating cylinder.

Preservative Processes.

Tests as to the direct influence of the preservative on the strength of various classes of timber should be conducted, as far as possible, with the exclusion of such factors as have been mentioned above. In other words, in testing the influence of zinc chloride on timber, all timbers tested should be subjected to a similar amount of steaming, kiln-drying or air-seasoning, so that the only factor to be considered would be the impregnation with the chloride. Tests to determine the influence of preservatives on the timber should consider the use of the preservative in varying quantities, for it is entirely possible that a preservative used up to a certain strength does not weaken the timber, while excessive use may weaken it considerably. The following preservative processes should be included in any series of tests:

1st.—Zinc chloride.

2d. —Creosote or tar-oil, and its various forms, such as spiritine, carbolineum, etc.

3d. —A combination of zinc chloride and creosote.

4th.—The Hassellmann or Barschall treatment. This process will involve the additional testing as to the influence of boiling timber in solutions at various temperatures.

5th.—The electrical process of timber treatment, using magnesium sulphate.

6th.—The Ferrell process, using various salts.

7th.—The creo-resinate process.

In making comparative-strength tests of treated and untreated timbers, it will be very desirable to eliminate, as far as possible, the variable strength factor found in untreated wood. To this end, the method used during the last year has been found very effective. The given log was sawed into two pieces, one half was treated, and the other half left untreated. The results, as to strength obtained after the two pieces were tested, eliminated this variable factor almost

entirely, because the two pieces came from the same tree, and from about the same region in its trunk. Mr. von Schrenk.

Subsequent Treatment.

The influence of drying or seasoning after treatment, on the strength of timber, has not been fully realized. It is believed that kiln- or air-drying treated timber will in many instances increase the strength of the material. A series of tests should be made in order to determine to what extent subsequent drying of treated timbers affects the strength of such material.

Several experimental plants are now under process of construction, where it will be possible to measure accurately the time during which timber is steamed or impregnated, the temperatures at which steaming or impregnation takes place, and also the pressure. Accurate scales are being fitted up to weigh large timbers, both before and after treatment, to determine the loss or gain in weight. It is hoped that the Society will discuss this phase of the timber-testing question very fully. Any suggestions which the members may have, referring to the foregoing general outline, or any new phases which it would seem desirable to consider, ought to be brought forward. The foregoing outline is simply a general statement, which is to be worked out in detail in the near future.

Gaetano Lanza, Esq. (by letter).—At the request of Mr. Pinchot, a proposed general outline for the tests of timber to be made by the Division of Forestry, of the Department of Agriculture, was submitted to him on June 23d, 1902. Mr. Lanza.

This general outline is quoted in their printed circular, beginning on page 3, and ending on page 8, and will not be repeated here; but the following topics will be discussed, viz.:

1.—Some general remarks on testing timber, including the importance of making the tests upon such sizes, and such kinds of timber, as are used by, or are useful for, engineers, and under the conditions of practice, especially as regards knots, cracks, crooked grain, and other defects.

2.—Criticism of the work performed upon this subject by the Division of Forestry, between 1891 and 1896, which was published in "Timber Physics," Volume II.

3.—The value and importance of the tests proposed in Series I, page 1, of the circular.

4.—Remarks upon certain portions of the circular.

1.—It is evident to every engineer that the timber beams used in practice are very rarely 2 x 2 ins. in section, that 4 x 12 ins., 6 x 12 ins., 7 x 16 ins., and larger, are sizes in common use, and that these latter may properly be called full-sized pieces.

Mr. Lanza. It is also plain, to anyone who uses timber in building, that full-sized pieces contain knots, cracks, crooked grain, and other defects, which would not be tolerated in the 2 x 2-in. pieces which, in the olden time, were used so extensively for tests, the results of which, as is well known to-day, do not furnish any constants suitable to use in designing timber structures.

Indeed, for any one kind of timber, the greatest influence upon its resisting powers is exerted by the defects stated, and their effect is even greater than that of the percentage of moisture, or degree of seasoning, though this latter ranks next in importance.

Anyone who has tested a considerable number of full-sized timber beams, and has attempted to estimate beforehand their strength and compare his estimate with the facts, will be thoroughly convinced of the truth of the statements made above.

Indeed, the writer knows, from personal experience, in the case of Spruce, that a careful consideration of the knots, cracks, crooked grain, and other visible defects will enable one who takes pains to keep himself in practice to predict the breaking strength of such a 4 x 12-in. beam within about 6%, the degree of dryness being considered only to such an extent as can be judged by the eye.

In the light of the above, it is plain that any experimental study of the resisting properties of timber which does not take these things into account is wholly unsuited to furnish such information as the engineer needs. Hence the only tests from which we can hope to derive information of value are those on full-sized pieces.

In making such tests, we are brought, at once, to a realization of the fact that there is a great variation between different pieces of the same lot, all suitable for use, the strongest being often three times as strong as the weakest. In practice, therefore, when, as is usual at the present time, the entire lot is used indiscriminately, the constants used in designing should be very considerably below the average values.

If the time should ever come when the engineer makes a selection between different beams or columns of the same kind of timber, that selection will be made mainly upon the basis of the knots, cracks, crooked grain, and other defects, while the determination of the actual strength will also involve, to some extent, a consideration of the percentage of moisture.

2.—As to the report of the work done upon Long-Leaf Yellow Pine, under the auspices of the Division of Forestry, between 1891 and 1896, the results of which were published in "Timber Physics," Volume II, the following observations should be made:

a.—By far the greater part of the work was performed upon small pieces, and the attempt was made to imitate that portion of the Munich tests which was made upon small pieces. Inasmuch as these results do not furnish values suitable for use, they will not be discussed here.

b.—The only results published in that volume which were obtained from tests of full-sized pieces may be said to be twenty-five beams from nine trees, all from one locality, if we call 4 x 8-in. pieces full-sized; otherwise they include only seven beams from four trees. Mr. Lanza.

The number of tests and of trees was wholly inadequate to justify the drawing of conclusions of value to the engineer, even if the tests had been made correctly.

c.—The testing machine used did not weigh correctly, on account of the friction of the cup-leather packings; and, whereas, after this had been criticized severely, Professor Johnson changed the construction of the machine to that shown in his book, "Materials of Construction," nevertheless, the results on full-sized pieces were all obtained with the incorrect machine.

d.—Pains were not taken, in the determination of the moisture, to make sure that the percentage contained in the pieces tested for this purpose was really the average of that in the entire beam.

e.—Therefore, it seems to the writer that the results of the tests published in "Timber Physics," Volume II, do not furnish such information as is needed by the engineer, and that, therefore, in the new tests, advantage cannot be taken of any of those results.

f.—In Circular No. 15, of the Forestry Division, no details are given, and hence it is presumable that the tests there reported were made in a manner similar to those reported in "Timber Physics," Volume II.

3.—Tests of the character described on pages 2 and 9 of the circular, under the heading Series I, are of very great importance, as they will serve to furnish quickly the information most needed by engineers, *i. e.*, the constants (compressive strength, modulus of rupture, and modulus of elasticity) that can be depended upon in any one kind of timber. For this purpose, of course, pieces of various qualities should be selected, including some of the poorest that would be suitable to use in construction. Indeed, the above is the character of the greater part of the tests on full-sized timber that have been made in the writer's laboratory, especially upon Spruce, Yellow Pine, and White Oak, as well as upon a few other kinds.

In the case of timber bought at the lumber yards, very little information, if any, can be obtained regarding its growth, seasoning, etc.; but, even without such information, we can obtain values for ready use for a number of kinds of wood, which would serve a very useful purpose.

4.—The writer will now discuss a few of the matters which are referred to in the circular, and which need some comment.

a. The circular does not contain any proposition for the making of time tests upon full-sized beams, a matter of very great importance. Tests of this character should be made at every station, in order to determine the effect upon all the constants, of subjecting the pieces to

Mr. Lanza. load for a long period. In the writer's laboratory, such tests have been carried on for periods varying from about five months to about three years.

b.—The two schemes for moisture determination, mentioned in the writer's outline, are not adapted to the separation of the volatile oils from the moisture, a matter of much importance.

The method proposed in the circular, for separating the two, will be a proper one, provided it can be shown that the three discs chosen in the manner described represent fairly the percentage of moisture in the entire beam.

The only way to settle this question is to make a preliminary investigation, to determine how (if at all) any discs can be chosen which will represent fairly the quality of the piece as to moisture. If the result of such an investigation should show (as the writer is inclined to think) that such discs do not represent fairly the entire beam, then a proper method to be pursued would be the following:

Determine the percentage of volatile oils in a set of three discs.

Determine the percentage of volatile matter in a set of three adjacent discs.

Determine the percentage of volatile matter in the beam from the remainder of the beam (*i. e.*, all except the six discs mentioned above), by the first of the two methods given in the writer's outline.

Determine the percentage of volatile oils in the beam by proportion.

c.—The tests for compression across the grain should be much more extensive than those proposed in the circular, in order to furnish information of value. They should include a considerable range of ratio of length to diameter of the pieces to be tested.

d.—It may be well to mention a few minor matters, as follows:

α.—The writer does not believe that the yield point of timber, even if it exists, can be found with sufficient accuracy to make the results of any value.

β.—From the transverse breaking load, the modulus of rupture can be calculated, but not the extreme fiber stress at fracture.

γ.—It seems to the writer at least doubtful whether deflections can be obtained with sufficient accuracy, if the load is to be continuously increased.

Mr. Johnson. A. L. JOHNSON, M. Am. Soc. C. E.—While the speaker has had very little to do with timber since 1895, except in the way of false-work construction, his former connection with the Government tests, during a period of two and one-half years, aroused in him an interest in timber physics which has not yet, and he trusts will never be, abated.

In the old days, we had much enthusiasm, but little money. Now, the speaker understands, they have much enthusiasm and much money. No more auspicious circumstances could be devised, and great results may be expected. In the spring of 1895 there were some discussions relative to the formulation of a broad and completely com-

prehensive scheme, embracing the whole field of timber investigation, but before anything had been done along this line the appropriation ran out, and the speaker's connection with the Division of Forestry ceased; and, as far as he knows, no small-scale drawing of the whole field has ever been made. Mr. Johnson.

Yet this is absolutely essential, not to the end that we may begin at the beginning and carry everything before us as we go, but for exactly the opposite reason; so that we may make investigations here and there, as exigencies may demand, or as suits our convenience, feeling comfortable in the assurance that each step made leaves one less to make, whatever the order in which taken. In the making of apparently entirely disconnected investigations, the fields, nevertheless, will overlap, and these portions will be done twice, and perhaps many times.

In the speaker's estimation, therefore, the thing to be done now is for the Forestry Bureau to prepare an outline scheme of all possible lines of investigation which, by our present knowledge, would indicate any profitable return. No doubt the Bureau would be glad to receive suggestions for such a scheme, and the speaker has the temerity to present one herewith for consideration. He does not regard it as satisfactory; in fact, it is extremely improbable that a satisfactory scheme could be prepared by any one man; and certainly none should be adopted except after extensive discussion by technical experts.

With a general plan for the whole work, the Bureau would then be in a position to receive suggestions from engineers, architects, manufacturers and others as to the necessity for immediate information along certain lines.

When we begin to consider the whole field of timber investigation, about the first thing we realize is, that engineers are not the only ones using timber, though, undoubtedly, they are the most strenuous in their demands. First of all, then, it becomes necessary to classify the uses of timber, and the speaker suggests the following segregation:

USES OF TIMBER.

Utilitarian.

Framed structures.
Piles.
Ties.
Tanks.
Walks.
Boxes, cases, etc.
Implements, tools, utensils, etc.
Instruments.
Vehicles.
By-products.

Mr. Johnson.

Æsthetic.

Finish.
Furniture.
Musical instruments.

With regard to the classification of the headings in the investigation scheme given below, a few words of introduction may not be out of place.

The eventuality hoped for is that we, or rather our children's grand-children, may be able to grow timber for a given purpose. This naturally suggests two main divisions in the investigation, one to determine the best uses of the timber we have, the other to find out how to produce what we would like to have. The first the speaker calls "Utilization," the second "Cultivation." The sub-headings are self-explanatory.

TIMBER PHYSICS.—GENERAL SCHEME OF INVESTIGATION.

UTILIZATION.

Physical Considerations.

Size of log.
Age of log.
Size of test piece.
Rate of growth (average).
Position in cross-section.
Position above ground.
Seasoning processes.
Preserving processes.
Artificial compositions.
Fire retardants.
Moisture.
Oils.
Defects.
Liability to diseases.

Cross-breaking strength.
Crushing strength, endwise.
Crushing strength, across grain.
Penetration.
Tensile strength.
Shearing strength.
Resilience.
  Load with no initial velocity.
  Load with initial velocity.
Resonance.
Polish.
Finish.
  Paint.
  Stain.
  Varnish.
Shrinkage or swelling.
Weight.
Length of life.
Chemical qualities.

Commercial Considerations.

Cost.
Present and prospective supply.
Reliability or uniformity of grade.
Characteristics by which wood may be identified.
Rules of inspection.
Relative suitability of different woods and treatments for different purposes.

CULTIVATION. Mr. Johnson.

Botanical Considerations.

Anatomical structure correlated with { Physical properties. / Site conditions.

Commercial Considerations.

Placing forests for most suitable site conditions.
Directing the use of timber so as to avoid needless waste.
Apportioning forests according to needs.
Harvesting for perpetual service.

Of the "Utilization" part of this scheme, practically the whole value will be summed up in the commercial consideration as to the most suitable timber and treatment for different purposes. The value of the second part is comprised in the determination of the relation between site conditions and anatomical structure, enabling us to locate forests where the trees will develop the desired qualities if properly cared for.

As may be inferred from the foregoing, the speaker does not approve of Series No. 1 of the scheme proposed by the Bureau, inasmuch as all tests made on timber bought in the open market will be wholly lost as far as the correlation with site conditions is concerned. This he deems to be a waste of time and money, not offset by any immediate advantage. In many cases the Bureau officials, themselves, would be unable to tell what kind of timber was being tested.

Series II to VI are necessary, but should all be made on material whose site conditions are known. A series on fire retardants might also be profitably added.

With regard to Series VI, the speaker, just before leaving the Forestry Division, had planned an investigation which it was thought would give the resilience of the material under loads applied with initial velocity. It was at that time considered impracticable to measure the energy of the blow directly, on account of the large number of ways in which the effect of the blow was dissipated, rendering it impossible to determine just how much was absorbed by the specimen itself.

It was proposed to turn rods, say 1 in. in diameter and 3 ft. long, rounded at the ends, all at the same condition of moisture, and, striking them on the end with a hammer, determine the pitch of the note produced. This note results from waves set up within the piece, and its pitch really represents the rate of transmission of stress through the specimen. A wood giving a high note would undoubtedly have a great impact resilience. Incidentally, this series might have been of considerable value to manufacturers of musical instruments.

Series VI should be made to include constant loads. An investigation of this sort was made in the former tests, whereby it was found that one-half the load required to break a beam in a few minutes would

Mr. Johnson. do so in an infinite time. But the series was very limited in scope, it being started only a short while before the work was stopped.

With regard to the old series of tests, the speaker believes they may be taken as conclusive, as far as the relative strength of *Pinus Palustris*, *Pinus Echinata*, *Pinus Cubensis* and *Pinus Tæda* are concerned; but not conclusive with regard to the other woods, nor as to methods of treating timber; except as to the bleeding of the Pines.

The details of execution of the Bureau's proposed scheme leaves little to be desired. In the speaker's opinion, however, there are one or two points needing more careful handling.

The method of obtaining the moisture contents by cross-section disks, although used in the first tests, and while fairly satisfactory for all kinds of tests except beams, is not satisfactory for the latter. Especially would this be true of large beams, or beams of varying size. The reason for this is that the interior of the beam usually contains more moisture than the outside, so that the ordinary stress-strain curve of the timber is modified by the varying influence of the moisture contents. The average moisture of the section, therefore, is likely to be much in error, as far as the influential moisture contents near the surface are concerned. This would make it difficult to compare results on large and small specimens. The large beams would show greater strength, relatively, than they really would have.

A satisfactory comparison could probably be obtained if the beams were all made of the same size, with a separate series to determine the influence of size, as was done in the first investigation. But a better method of obtaining moisture contents should be devised. The speaker believes this can be done by cutting the disks in slices parallel to the neutral axis and giving weight to the different percentages in the different pieces in proportion to their distance from the neutral plane. At any rate, this should be done until it is determined that the method alters the results too slightly to be worth the trouble. But a very slight change in moisture makes a large change in stress at the low percentage for kiln-dried material, and the speaker believes there will be a considerable difference in results shown by this method.

If, for beams, the old disk method is poor, the method of obtaining the moisture contents by weighing the whole stick is very much worse. The moisture in the ends of a beam cuts practically no figure in the result, but would, by such a method, be given as much weight as that in the middle.

The Bureau, however, has not seriously considered the adoption of the above suggestion.

The speaker would counsel small minor tests and many of them, making size, with associated defects, a separate investigation, as shown in his scheme. The reason for this is that, do what we will, there are

Mr. Johnson.

many more unknown quantities than equations in such work, so that results can only be obtained by a large number of tests. If we increase the number of variables we must increase the number of tests in the same proportion.

To use, as a minimum unit, beams 4 x 12 ins. x 14 ft. would about double the variables, as compared with what they were with the original beams, 4 x 4 ins. x 6 ft.; hence it would take about twice as many of the larger beams as of the smaller ones to be able to draw scientific conclusions of equal value regarding the strength of different species. In other words, it would take fourteen times as much timber for the large tests as for the smaller ones, to obtain the same accuracy.

The circular states that it is proposed to load the beams in the middle. This is a poor method for anything but the most homogeneous material. It compels a break at a certain point, whereas the desire may be to break at a different point. The results, therefore, are too high. This was all threshed out in the original investigation, and it was found much better to have a uniform bending moment for some distance (12 ins. was used) in the middle.

The speaker, not being at present a user of much timber, will leave it to those who are to suggest the important parts of the general scheme requiring immediate investigation. But there is one suggestion he would like to make to the Bureau, and that is that they prepare a handbook, of pocket size, for the identification of timber and of trees in both summer and winter.

Every engineer would feel the value of such a book. Of what service to him is it for the Department to say that one kind of wood is much better than another for certain purposes, when he is unable to tell whether or not he gets it?

The speaker remembers some of the results on shear in beams obtained in the first investigation. Some of the largest beams failed by shearing along the neutral plane, having become case-hardened, as they say, by drying too rapidly and hence checking badly; being a case which is likely to occur very often in practice. They were of Long-leaf Pine, and failed at about 150 to 200 lbs. per square inch, whereas the small-sized shearing specimens of that wood would have shown a shearing strength of from 600 to 700 lbs. per square inch; and the tables which were prepared by the Forestry Bureau, in Bulletin No. 12, cautioned a much greater factor of safety in big beams than in small beams, on that account.

The speaker would never design a large beam to take more than about 100 lbs. per square inch of shearing stress along the neutral plane. This was one reason why, in the Bureau's design of timber-trestle bridges, corbels were used, as the bolts running through the corbels at the ends of the stringer would assist it in increasing the shearing strength at that point.

Mr. Russell. S. BENT RUSSELL, M. Am. Soc. C. E.—If it is proper to speak of matters of detail, in discussing this subject, the speaker would like to offer one or two suggestions which seem to be practical.

In the tables of strength of beams, published since the Government investigation was started, the strength of short beams is given as being independent of the length. That is, when the length is short in comparison to the depth, the central breaking load of the beam would be independent of the length.

It has been shown, of course, that in the case of a beam which fails by shear along the neutral axis, the theoretical breaking load is the same for different lengths when the cross-section is the same. The speaker, however, has seen no experimental data which would be of use in the actual designing of beams of this character. To make the point clear, suppose we have a wooden beam, 16 ins. deep and having a clear span of 6 ft., loaded at the center. How should the breaking load be determined? From the published tables, such a beam would not carry any more than a similar beam of 12 ft. clear span loaded at the center. It seems quite probable, however, that the shorter beam would really sustain a greater load. The actual length of the former beam would be somewhat more than 6 ft., to provide proper end bearings; and the load, in practice, would have to be distributed enough to prevent local crushing. These conditions would almost certainly affect the tendency to shear along the neutral axis. It is not unlikely, too, that the shorter the beam the greater would be the effect of these conditions upon the breaking load.

Beams of the kind in question are used to a large extent in engineering construction, and it would certainly be wise to determine the laws that govern their strength. The speaker would suggest that a series of tests be made with properly designed wooden beams where the span is short compared with the depth of the beam, as such a series of tests, properly planned and executed, would be of great commercial value.

Another subject for investigation is the effect of water-soaking upon the strength of timber; the effect of soaking, under different pressures and for different lengths of time, and for different kinds of timber. An engineer often has occasion to use timber under water, and would therefore like to know what the strength of that timber is after a certain time of immersion. The data now obtainable are by no means sufficient. It is true that tests have been made of the effect of percentage contents of moisture upon the strength of certain kinds of timber, but that is not enough. The speaker would suggest that an attempt be made to obtain more data to cover this point.

These suggestions are the fruit of actual problems in the speaker's practice; and, without doubt, many engineers can recall similar problems of their own.

Mr. Hatt. W. K. HATT, Assoc. M. Am. Soc. C. E.—The speaker desires to comment upon certain matters brought up by Mr. Johnson. Touching the relation to the general interests of forestry of tests to determine unit values of the strength and stiffness of timber, it seems to the speaker that any factor affecting the use of timber has an influence upon the work of the forester. For example, if the true value of such a wood as second-growth Loblolly Pine should be determined and its use promoted, the work of the forester in bringing about a conservative management of forests would thereby be greatly aided and the interests of the public promoted.

The outline that the speaker has in mind, of an ideal scheme of investigation of all matters relating to timber, agrees with that presented by Mr. Johnson. The pursuit and successful completion of a scheme of this kind is a very attractive ideal, and, in the speaker's opinion, therefore somewhat dangerous, because impracticable. The investigator would soon find himself in a labyrinth. It is almost certain that this somewhat Utopian scheme would not be carried to a successful conclusion, and in the endeavor to use the same material to supply data for different parts of the general field of investigation the investigator will probably fall between two stools. For instance, the sticks used in construction are taken from a log in a different way from those that are best adapted to yield representative values for the mechanical properties of the tree. Again, the German investigators, in order to determine the effect of minor conditions upon the strength of wood, perform tests on small sticks which do not contain knots and other accidental defects; whereas, in this country, large sticks are tested for the very reason that they do contain knots. The very object of one series of the proposed investigation is to determine the extent to which these knots and other defects lower the strength of the timber.

With regard to Mr. Johnson's programme, which comprehends all possible relations between growth and strength, it is certain that only a few of the possible conditions of growth have any important influence. A knowledge of the relation of many of the factors listed by Mr. Johnson would be interesting; it is certain that the effect of these factors could not be isolated and determined. A knowledge of many of these would not be of sufficient value to justify the expenditure of the necessary time and money. Roth's study of the Bald Cypress*, in which trees were collected from various sites, brought out the fact that individual variations and variations within one and the same tree are fully as great as the differences brought out in the woods from different localities. Roth's study of the White Pine† also showed that the specific weight (which varies directly with the strength) of wood

* Circular No. 19, Division of Forestry.

† Circular No. 22, Division of Forestry.

Mr. Hatt. from swamp trees is no heavier or lighter than the wood from upland trees, the trees from New England differing apparently in no way from those of the Lake region or North Carolina. No useful results, to the writer's knowledge, have followed the attempts which have been made to determine by a series of formal tests the relations which exist between conditions of growth and quality of timber.

Has it not occurred to Mr. Johnson and others that the collector operating in the forest can only describe the conditions which exist at the period of the visit, whereas the tree has been growing in some cases two hundred years? The collector in the market knows more of the history of the tree than does the collector in the forest, for the former sees the history in the annual rings.

Another instance in which one important object of tests of timber is frustrated, by the endeavor to kill two birds with one stone, is the European method of selecting test specimens so that values may be obtained representing the average mechanical quality of the tree. The Germans quarrel with the former Government timber tests because the manner of taking out the test pieces, in their opinion, did not show the average quality of the tree. Now, even if some method were agreed upon, for the selection of test pieces that would serve this purpose, such an average quality would have no practical meaning, for the reason that the practical questions to be solved have relation to only part of the wood of the trunk. To obtain mechanical values that shall have a useful significance for the designer or manufacturer, tests should be made upon that portion of the trunk that is actually used. A factor representing the strength of the whole trunk has but little meaning if desired to determine, for instance, the relative value for carriage construction of second-growth or virgin-growth Hickory, or the relative value of Swamp White Oak or Upland White Oak. The comparisons should be made upon the wood taken from that part of the trunk which is available to the manufacturer for such purposes.

Mr. Johnson will, no doubt, agree that, for the purpose of establishing the mechanical value of structural timber, it is necessary to test large sticks. He believes, however, that these should be taken from the forest, in the interest of general scientific knowledge. In favor of sticks as obtained on the market or at the mill, the speaker would point out the following advantages:

(1) Economy.

(2) The certainty that the material represents an actual commercial product.

(3) That all the essential facts, certainly all of those that the constructor can, in any way, control, can be determined with reference to the history of the timber. In case of large structural timber, the lumber dealer can furnish information as to the mill from which the

timber was procured, the month in which it was sawed, and the conditions of seasoning. In case of smaller sticks of hardwood, procured at the mill, this information is also available. Knowing the mill, the forest conditions from which the mill draws its supply can easily be determined. A competent dendrologist has no difficulty in determining the species of at least 95% of the timber on the market by an examination of the wood fiber. At any rate, for the purposes of obtaining unit values for the design of framed structures, if two sticks of timber of closely related species, as, for instance, Long-Leaf Pine and Cuban Pine, are so closely alike in weight and appearance of fiber that an expert cannot distinguish between them, the confusion of one species with another is a matter of no practical importance. Mr. Hatt.

The speaker would digress in order to state his personal opinion as to the most economical method of obtaining knowledge of the effect of conditions of growth upon the volume and character of the wood produced in the forest. He believes it to be an unnecessary and rather clumsy method to cut down many trees, and submit them to the action of the testing machine in order to determine the relations sought. As a matter of fact, many practical lumbermen, from general observation and experience, have a qualitative knowledge of the effect of conditions of growth on the value of the wood. This knowledge must always be largely inferential and can never be precise. The mechanical work of the testing machine, in the speaker's view, should establish the relations between specific weight and strength; between moisture and strength; between different characteristics of fiber and strength; and should determine the relations which exist between the moduli of strength exhibited by any species under different kinds of loading, to the end that, from the results of one kind of test, the strength may be predicted under another kind of loading. The testing machine can also determine the mechanical effect of different technological processes on identical material. In this way, in general, the testing machine establishes the relation of certain physical appearances and properties to the strength under loading. The number of cases is not very great in any one species, and it would be a comparatively simple matter to determine these relations.

Now, the botanist and the forester, in connection with lumbering operations, or a study of forests, can easily determine the character of wood produced under different growth conditions. With the information derived from the testing machine at his hand, he can easily infer the mechanical worth of the different kinds of wood produced under given growth conditions. In this way, a single individual in a few weeks in a forest can learn more than an entire organization of testing engineers in many years. This is the speaker's personal view,

Mr. Hatt. however, which has not been submitted for criticism to any botanist or forester.

A useful end for timber tests at the present time is the determination of which of the so-called inferior species will prove the best substitutes for those woods whose increasing price is gradually placing them out of reach for certain purposes. This problem involves the determination, in a quantitative measure, of the difference in strength and durability of two woods which are in use for the same purpose, so that an economical selection between these two may be made. This remark applies, for instance, to material for cross-arms for telegraph poles, box boards, joists, etc.

In answer to Mr. Russell's question as to the strength of a short block which is under a bending load, the speaker would say that tests have been made to determine the relation between the strength of sticks of long and short span by Mr. Hood, Chief Engineer of the Southern Pacific Railway. It is known, of course, that large sticks of short span must be designed for horizontal shear, and in extreme cases, possibly, for compression along the side of the grain at the point of application of the load.

There is every reason to believe, from actual tests and general experience, that the effect of soaking timber is to improve its durability, because of the fact that such soaking removes the sap. The process of soaking also renders hardwoods less likely to warp. Of course, if soaked timber is tested immediately after removal from the water, the strength is less than that of dry timber; but there is no reason to believe that, if the timber which has been soaked is subsequently dried, there will be any diminution in the strength due to the previous soaking.

In forming views of the method of procedure for testing timber, one should remember that there are endless possibilities in respect of refinement of methods, and the exercise of judgment is necessary in rejecting useless refinements. One must also choose between those investigations which are of scientific interest and those which have some outcome of practical use. The following are the matters which appear to the speaker to be worthy of investigation at present:

With Reference to Internal Relations of the Testing Process.

(1) The relation between the physical and mechanical properties, so that, in future, from the result of a single test the engineer may compute the strength under the several kinds of loading, or the botanist may judge of the value of woods from inspection.

(2) The effect of moisture and speed of application of the load.

(3) In a quantitative measure, the weakening effect due to knots and defects of structure.

WITH REFERENCE TO KNOWLEDGE OF PROPERTIES OF SPECIES. Mr. Hatt.

(4) To ascertain the value of inferior woods now used in market, as, for instance, second-growth Loblolly Pine; and of species that will come on the market in the future, as, for instance, Western Hemlock and Spruce. This knowledge would allow a proper choice of substitutes for woods now becoming scarce. The work of the forester, in conservative forest management, will be aided thereby.

WITH REFERENCE TO TECHNOLOGICAL PROCESSES.

(5) To study the best methods of seasoning, and the effect of these on the strength and durability.

(6) To study methods of preserving; their efficiency; their effect on strength; and the best species for use.

(7) To work out special problems, such as the determination of sizes of cross-arms of telegraph poles or box boards, in order to economize material.

In answer to Professor Lanza's remarks, the speaker would say that provision is made for "time tests" on full-sized timbers; that preliminary investigations show that the corrections to the moisture determinations due to the volatilization of the oil in the wood are of minor importance, and may be neglected, except in the cases of very fat Long-Leaf Pine. The correction is in ordinary cases a fraction of 1 per cent.

The present state of knowledge would lead to the belief that the variation in the moisture along the beam is small in comparison to the variation throughout the cross-section. The testing of timber in the green condition will avoid many difficulties arising from the effect of differences of moisture on the strength of the timber, for the reason that after timber has absorbed 33% moisture, no additional weakening effect accompanies any further absorption. A sufficient number of beams are to be tested after a thorough drying out to determine the relations of the strength of dry to green timber. The tests for compression across the grain have been planned to include full-sized pieces, in accordance with the suggestion of Professor Lanza.

According to the speaker's experience, the yield point of timber is a limit of sufficient definiteness to form a proper and useful basis for the designer. It is recognized that the modulus of rupture is not the same as the extreme fiber stress at fracture. In case of large beams, which deflect from 2 to 3 ins., or even more, it is sufficiently accurate to read the deflections to $\frac{1}{100}$ in. This can be done under a continuously increasing load.

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PAPERS AND DISCUSSIONS.

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LOADINGS FOR RAILROAD BRIDGES.

An Informal Discussion at the Annual Convention, June 11th, 1903.*

SUBJECT FOR DISCUSSION:

"In view of the Increasing Weights of Rolling Stock, for what Loadings should Railroad Bridges be Designed?"

By Messrs. HENRY W. HODGE, J. W. SCHAUB and EMIL SWENSSON.

Mr. Hodge.

HENRY W. HODGE, M. Am. Soc. C. E. (by letter).—The constantly increasing weights of rolling stock on railroads is a subject which affects most vitally the safety of all bridges on such roads; and, as few operating departments have made proper allowance for such increase in ordering these structures, it has been necessary to remove many good bridges and replace them with heavier ones within very short periods; generally much shorter than their natural life under loads for which they were designed. It is properly the field of the operating departments to keep the probable increase in loads in view when giving data to the construction departments; but though these live loads have been increased more than 100% in the last twenty years, with no certain signs of a maximum limit, it is seldom we find an operating manager who thinks there is the slightest necessity of designing bridges for greater loads than the latest locomo-

*The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV, p. 71.)

Communications on this subject received prior to September 25th, 1903, will be published subsequently.

tives he has ordered; and the writer has known railroads to order bridges on the same line for three different live loads within two years, so that the first bridges were overstrained 33⅓% within two years after they were completed. Mr. Hodge.

This appears to be a very short-sighted policy, and yet it is a question whether the bridge engineer is in a position to correct it, as his situation places him in the delicate position of appearing to wish to increase his remuneration if he suggests increasing the weight of a structure over what he is ordered to design. As stated previously, however, there is no sign that the maximum rolling loads have been reached, and if they are to continue increasing at anything like their past rate, it is certainly advisable for railway managements to give the subject more attention than it has heretofore received. It is evident to all engineers, and men in other departments of railroad construction and operation, that the tendency is constantly toward the moving of freight in larger units, and it is a well-established fact that the extremely low cost per ton of moving freight on American railroads has been reached by this use of larger units than are used elsewhere.

It seems to be agreed by all operating managers that increased economy would be further secured by enlarging the loads carried by each locomotive, and, therefore, it would appear that the final maximum weight of locomotive will only be found when the sustaining power of the roadbed is reached, or when it is impracticable to get more weight on the drivers of locomotives. We often hear the statement that locomotives cannot be made much heavier because the rails will not carry more, but this statement has been made continually for many years, and, all the time, the weights of locomotives have been steadily increasing and the weights of rails have been increasing about proportionately. The writer cannot see that the section of rails can ever be a bar to increasing live loads, as these rail sections can be increased to whatever point is desired, larger tie-plates being used, and it would appear that a much more serious difficulty to be overcome is the supporting power of the earth roadway and the rail joints. Ties cannot be spaced much, if any, closer than they are now, if bedded in the present manner in ballast, as the present spaces are about as small as possible to allow of proper tamping of ballast to hold the track in line and surface. If more bearing surface, with the present general arrangement, is desired, it will probably have to be gained by lengthening the ties, and there seems to be no good reason why this should not be done.

With the present arrangement of ties, bedded in good stone ballast, the pressure on the earth roadbed, from a driving axle weighing 60,000 lbs., spaced 5 ft. from center to center, can be assumed to be spread evenly over an area of 5 x 10 ft., or 50 sq. ft., giving a press-

Mr. Hodge. ure of 1 200 lbs. per square foot. If this is doubled, for impact, there would still be only a little more than a ton to a square foot, which does not seem to be as much as a well-compacted earth roadbed should stand. Of course, this absolute pressure is not entirely the governing feature in the permanency of way, as it is necessary to have the ties held in place so rigidly that they will not get out of line and surface. But it must be borne in mind that the maximum loads hauled will be heavy freight trains at a comparatively slow speed, and, in all probability, they do not have nearly as injurious an effect on the permanent way as the much lighter passenger loads moving at greater speeds. Thus it would appear that there is no reason why the maximum live loads should be determined by the supporting power, or the rigidity, of the permanent way.

There still remains the question of what maximum weight it is mechanically possible to put over a driving axle, and the writer feels confident that this will be the governing point of the extreme axle loads. Locomotive builders have had their ingenuity taxed already to get the necessary weight on the driving axles to prevent slipping, and yet keep within the clearance height, and anyone looking at the modern heavy-grade locomotive is immediately struck with the fact that the top of the boiler is so near the upper clearance line that there is only room enough for the smallest apology for a stack and steam dome.

It must be remembered that the height and width of the locomotive is practically limited, and, as the present distances from center to center of drivers are made such that these wheels are as close together as possible, there seems to be no further space to get in more weight, unless the railroad clearances of height and width are changed, and this would mean practically rebuilding the railroads. It may yet be possible to decrease somewhat the size of the driving wheels and thus give more height above the axles for weights, but the modern heavy-grade engines have wheels less than 5 ft. in diameter, so that there is not much room for any considerable change in this direction.

As far as the writer has been able to get opinions from expert mechanical engineers engaged in the design of locomotives, it seems probable to them that the final maximum axle loads cannot practically be increased more than 15% above the present maximum axle loads, and the writer believes this to be a fair limit.

The heaviest locomotives for which the writer has seen any data are those built for the Atchison, Topeka and Santa Fé Railroad, weighing, without tender, 232 000 lbs. on five driving axles, and 27 800 lbs. on the truck, making 232 000 lbs. on a driving-wheel base of 20 ft., or 259 800 lbs. on a total wheel base of 28 ft. 11 ins., all as shown in the diagram, Fig. 1.

Mr. Hodge.

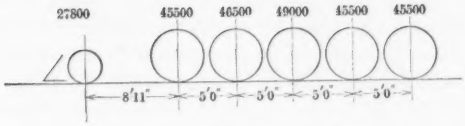


FIG. 1.

Those built for the Pittsburg, Bessemer and Lake Erie Railroad weigh 225 200 lbs. on four driving axles, and 25 100 lbs. on the truck, making 225 200 lbs. on a driving-wheel base of 15 ft. 7 ins., or 250 300 lbs. on a total wheel base of 24 ft. 4 ins., all as shown in the diagram, Fig. 2.

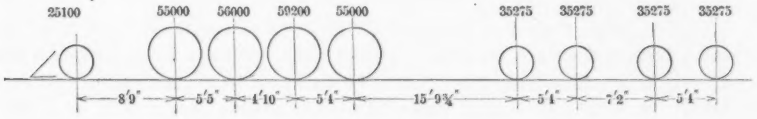


FIG. 2.

The latter engine is the heavier per linear foot, and the heaviest single driving axle carries 59 200 lbs., with an average for each driving axle of 56 300 lbs. If 15% be added to this average the result would be 64 745 lbs. per axle, and, from this, the writer is of the opinion that a locomotive having four driving-axle loads of 65 000 lbs. each will be sufficient to cover the extreme probabilities of rolling loads.

The tender of this Pittsburg, Bessemer and Lake Erie Railroad locomotive has 35 275 lbs. on each of four axles, and increasing these by 15% gives 40 566 lbs.; but there are greater possibilities of increasing tender loads than there are for driving loads, therefore the writer would set the maximum tender wheel loads at 42 000 lbs. per axle.

If one forward truck axle is used, taking 32 000 lbs., the result will be an engine weighing 292 000 lbs., followed by a tender weighing 168 000 lbs., making a total of 460 000 lbs., complete.

It is hardly necessary in this general discussion to go into the detail of spacing of wheel centers for this theoretical maximum load, but the spacings now generally used in bridge specifications (which do not vary greatly) seem to be about correct, except the distance from the last engine driver to the first tender wheel, which is now generally 8 or 9 ft., and which probably should be increased to 14 or 15 ft.

The following uniform load still remains to be determined, and the heaviest loaded steel cars that the writer has been able to find are the iron ore cars, in use on the Algoma Central Railroad, which weigh 44 000 lbs., carrying a net load of 100 000 lbs., making a total load of 144 000 lbs. in an over-all length of 24 ft., thus giving 6 000 lbs. per linear

Mr. Hodge. foot, and if this again be increased by 15%, the result is 6 900 lbs., say 7 000 lbs. per linear foot. The writer, therefore, is of the opinion that it will be safe to use, as the probable maximum live loads for present railroad clearance dimensions, two locomotives, weighing 260 000 lbs. on drivers, and 460 000 lbs. complete, with tender, followed by a uniform load of 7 000 lbs. per linear foot. Of course, it is not necessary or advisable for all railroads to adopt any such maximum loads, as few roads will ever need such an extremely heavy class of rolling stock, but this suggested maximum load is only intended to apply to such roads as have very heavy grades, and are looking forward to hauling eventually the greatest possible units over such grades. It certainly is not, and never will be, practical to adapt any particular set of live loads to the many railroad systems operating entirely different classes of traffic, under entirely different conditions.

It is hoped that this suggested maximum load may lead to a full discussion of this important subject, and perhaps bring about more foresight in the ordering of new bridges, as such foresight will certainly be a benefit to the railroad corporations, even if it is at the expense of the bridge designers and constructors whose natural preference would be to keep replacing light bridges, rather than build but one in a life-time.

Mr. Schaub. J. W. SCHAUB, M. Am. Soc. C. E.—The loading known as E-50, in Cooper's specifications, is now commonly used as a standard loading for railroad bridges. This provides for two engines weighing 355 000 lbs. each, including the tender, in working order. Bridges, if properly designed for this loading, will be able to carry with perfect safety a load fully 50% heavier than provided for. This means that the weight of engines can approach a total of 275 tons, before it would be necessary to even consider the renewal of the present bridges. When this loading has been reached, the present form of roadbed will long have dissappeared. The speaker is not prepared to say what is to take its place, but if engineers can feel assured that steel bridges, as now designed, will carry any load that the present form of roadbed will be able to bring to them, that is all that should be expected of them. Between the roadbed and the bridges, it seems to the speaker that the bridges have the advantage just now, and he considers the E-50 loading to be more than ample to carry anything that can be carried on the present form of roadbed.

Mr. Swensson. E. SWENSSON, M. Am. Soc. C. E.—The speaker concurs in the last remark of Mr. Schaub, that it seems unnecessary for the present to consider any heavier loadings for railroad bridges than those of the heaviest engines mentioned by Mr. Hodge as being in actual service, and for which Mr. Cooper's typical loading, E-50, is about the equivalent; as this load seems to be the maximum that can be imposed upon the soil of some embankments and side-hill roadbeds.

Mr. Swensson.

The above-mentioned heaviest engines go daily over bridges designed for somewhat less loading, without showing any effect on the bridges, but this is not always the case with the adjoining roadbed. It therefore indicates that, until some method of strengthening the roadbed is adopted, the engine-load should not be increased and consequently no increase should be made in the loading for railroad bridges.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE LEVEE THEORY ON THE MISSISSIPPI RIVER.

An Informal Discussion at the Annual Convention, June 10th, 1903.*

SUBJECT FOR DISCUSSION:

"In the Treatment of the Mississippi River, is the Levee Theory Justified by Experience?"

By Messrs. B. M. HARROD, L. W. BROWN, J. A. OCKERSON and L. M. HAUPT.

Mr. Harrod. B. M. HARROD, Past-President, Am. Soc. C. E.—"In the Treatment of the Mississippi River, is the Levee Theory justified by Experience?"

The question whether a theory is justified by experience is hardly fair, when its application is quite incomplete, as is the case on the Lower Mississippi River, where the levees have, as yet, neither the grade, section nor extension considered necessary, and the present contents, in cubic yards, is not more than two-thirds of that required by the adopted standard.

The discussion of the subject, however, is opportune, as a recent flood of magnitude has excited interest and afforded much information.

The justification of the "Levee Theory" is involved in such changes in the bed of the river, as a flood channel, as result either

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV., p. 71.)

Communications on this subject received prior to September 25th, 1903, will be published subsequently.

from natural causes or from an increase of the discharge by levees, during more than bank-full stages. If the bed is rising, or the capacity is otherwise reduced by natural and continuing conditions, the completion of a levee system will be prolonged, if not made interminable. If the bed is not rising, and the waterway is maintained or improved, either by deepening or widening, by the discharge of a larger volume at higher velocity, then the problem, though large, is simple and certain. Mr. Harrod.

The Mississippi River Commission, therefore, has given careful investigation to such changes since its appointment. Local and seasonal movements are constantly going on. At certain stages bars build up and pools scour. At others this process is reversed. Besides this, there is a general down-stream and snake-like movement of the sinuosities of the stream. The current binds against the upper and is slack against the lower side of points. Therefore the points, with their opposite concavities, move slowly downward from erosion on the upper, and accretion on the lower, side. The location of the pools and bars has a definite relation to the curvature of the bends, the former lying in the concavities, alternately on the right and left banks, and the bars at the nodes or reversion points between the pools. Hence, as the bends move down stream, the bars and pools move with them. Again, as the result of caving on one and accretion on the opposite bank, the river shifts sideways. Instances are not wanting where this movement has amounted to its entire width in fifteen or twenty years.

It is evident that with these unstable conditions but little can be learned from isolated or scattered soundings. A cross-section line over a bar may, in a few years, lie through a pool, or the river may have slipped to one side, leaving it on dry ground.

In the years 1881, 1882 and 1883, the Commission made an exact and detailed survey of the river from Cairo to the head of the Passes, a distance of 1 063 miles, with cross-sections averaging about four to the mile, and seventy-five soundings to the line. There was no better way of investigating this difficult and important question than by repeating the survey. This was done in 1894, 1895 and 1896, after an interval of thirteen years, over that part of the river where the levee system had been most improved during the interval, from the mouth of White River to Donaldsonville, La., a distance of 472 miles. This second survey was made in greater detail, in order that it might better serve for future comparisons.

There is a limit to the value of the results obtainable even by this exhaustive process, of which the Commission was aware, but no better method seemed available. A comparison between the two surveys would be conclusive in proportion to the similarity of the stage conditions preceding them and prevailing while the parties were in the field. Each

Mr. Harrod. survey was of such magnitude and detail as to require several months, and it was improbable that there would be a close repetition of the conditions of the first during the second.

Both surveys and the analysis of their elements were made under the charge of J. A. Ockerson, M. Am. Soc. C. E., and his detailed report on them is found in the Reports of the Mississippi River Commission for 1896 and 1897, published, respectively, in the sixth and fifth parts of the Reports of the Chief of Engineers for those years.

The following conclusions from his study of the conditions are well founded:

The differences found in these two surveys do not necessarily represent all the changes or the resultant of all the changes that may have taken place between them. During this time the conditions of the river bed may have varied in both directions from those found in either survey. They should, however, indicate any trend, or persistent and progressive change that has taken place. This general tendency seems to be toward a channel more uniform in depth and of greater capacity.

Table No. 1 gives the results from the Arkansas River to Vicksburg, 200 miles.

TABLE No. 1.—Relation of Elements in 1894 to those in 1881–82.

	Low water.	Medium stage.	Bank-full.
Width	+3.6 per cent.	+8.3 per cent.	−0.08 per cent.
Mean depth	−6 "	−6 "	+4.5 "
Area	−3.6 "	+2.7 "	+3.1 "
Hydraulic radius			+3.25 "

A composite comparative diagram of the sections in this part of the survey is shown in Fig. 1.

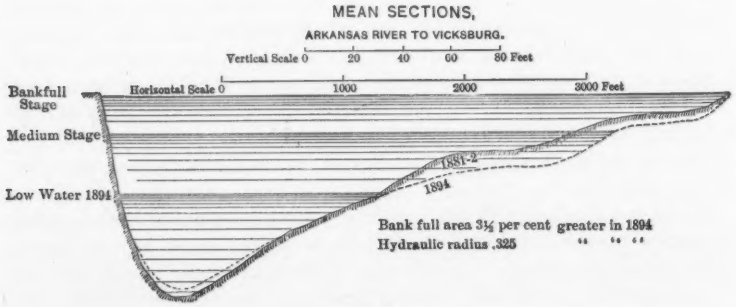


Fig. 1.

Mr. Harrod.

The mean of the results from Vicksburg to Donaldsonville, La., 272 miles, is given in Table No. 2.

TABLE No. 2.—RELATION OF ELEMENTS IN SURVEY OF 1895–96 TO THOSE IN 1882–83.

	Low water.	Medium stage.	Bank-full.
Width	+3.6 per cent.	+3.8 per cent.	+7.5 per cent.
Mean depth	−5.9 "	−8.1 "	−8.9 "
Area	−3.8 "	−0.8 "	+1.4 "

The conditions under which the two surveys from Vicksburg to Donaldsonville were made were so different as to give abnormal results. The first (1882) was after the greatest recorded flood and on the rise of the succeeding one, which was of considerable magnitude, while the last (1895–6) was preceded by two seasons of extreme low water, and a very moderate intermediate flood, during which sediment transported from above would be deposited in the lower part of the river, particularly below Red River, where a relatively large low-water section, flat slopes, and correspondingly small velocities are found.

A duplication of the survey of 1881 is now being made over that part of the river from Cairo to the mouth of the Arkansas, along which the levee system has been much extended since 1895. In the future, at proper intervals of time, similar resurveys will be made over the entire river, until they yield indications of a persistent and progressive change.

It may be assumed that the low-water plane conforms to the shape of the river bed, and that any elevation or depression of the latter, as the result either of natural causes or of levee building, will be recorded in the low-water gauge readings. The improvement of levees during the past twenty years, and their effect in increasing the height of floods, has been most marked in the 500 miles of river in which are included the gauge stations of Fulton, Memphis, Greenville and Lake Providence. There has, as yet, been no levee building which has affected the flood stage at Cairo. The effect on the bed of the river, therefore, may be observed by comparing the low-water stages at the points where levee improvement has been greatest with those at Cairo where no influence of the kind has been felt.

Prior to 1882 the United States had built no levees, and the insufficient and incomplete State levees existing at the time were badly wrecked by the flood of that year, which left them in quite an unserviceable condition.

If the average of the low waters at the points mentioned above, which have been selected as fairly representative, for the five years

Mr. Harrod. following this disaster of 1882 (1883–84–85–86–87) and that of the last five years (1898–99; 1900–01–02) be compared with the averages of the low waters at Cairo during the same two periods, as a standard, there will be observed, during the latter period an average relative depression of the low-water surface of 0.74 ft. at Fulton, 0.68 ft. at Memphis, 1.60 ft. at Greenville, and of 1.89 ft. at Lake Providence.

These reductions of the low-water plane are indicative of a depression of the bed, and are proportionate to the duration and degree of levee maintenance and improvement in the vicinity of the gauge stations mentioned.

Table No. 3 will make this statement clearer.

TABLE No. 3.

Average low water.	Cairo.	Fulton.	Memphis.	Greenville.	Lake Providence.
1883–87	5.21	4.50	2.57	5.56	4.04
1898–1902	5.35	3.90	2.03	4.10	2.29
Difference in averages	+0.14	−0.60	−0.54	−1.46	−1.75
Reduction below Cairo, 1898–1902		0.74	0.68	1.60	1.89

It was observed, in the great flood of 1897, that:

"The first gauge below Red River to exceed its previous record was the lowest one on the river, at Fort Jackson. The next was the Carrollton gauge, and so on, up to Red River, where the gauge did not exceed its previous record until sixteen days after the Carrollton gauge had done so. When the Carrollton gauge had reached its previous maximum, that at Red River still lacked 1.6 ft. of the height which had produced that maximum."

The same prematurity of rise at the lower gauge stations occurred during the present year. In a discussion of this phenomenon by Major Derby, M. Am. Soc. C. E., in the Report of the Mississippi River Commission for 1900, it was considered as due to one of only three causes: (1st) a raising of the bed of the river below Carrollton; (2d) the effect of crevasses and their closure, or (3d) an increase of the carrying capacity of the channel between Red River and Carrollton, by which the resistance to discharge and the slope over that 200 miles of river was reduced. His analysis of flood waves ranging in height at Red River from 19.3 to 45.2 ft. between the years 1872 and 1899, discredited the first two causes, and led to the conclusion that the discharge capacity of this part of the river had been increased during the period under consideration.

Besides these extended comparative observations, others of a more local character have been made, in connection with crevasses or

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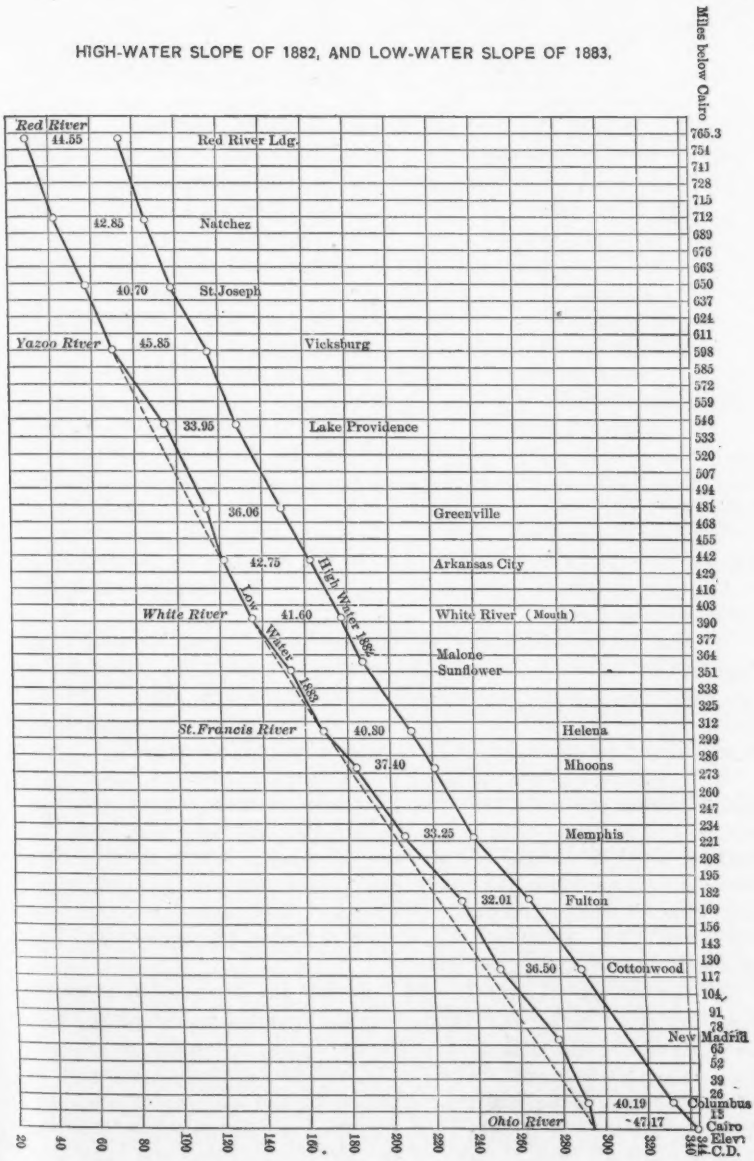


FIG. 2.

Mr. Harrod. temporary outlets, as at Malone's, Riverton, Bolivar, Mound Place, Morganza, Bonnet Carre and Cubitt's Gap. Whenever the resurvey was made after the occurrence of an outlet, it showed a reduction of the cross-sectional area below. When made after closure, an enlargement has been observed.

When, in 1880, the river was first subjected to continuous observation, the levee system was in its infancy, some basins were entirely unleveed, and such crude levees as existed were breached at many places by every high water. It was then noticed that the rise and fall was very different at different places. When classified, the greater annual oscillations, amounting generally to about 45 ft., were found at or near the mouths of the tributaries, the Ohio, St. Francis, Arkansas, Yazoo and Red rivers, while the lesser ones, averaging only about 35 ft., were observed at intermediate points along the fronts of the great basins drained by these tributaries, as at Fulton, Memphis, Greenville, Lake Providence and St. Joseph.

The gauge readings, when plotted, showed a smooth and regular high-water slope, while that of the low-water slope was quite irregular, being depressed about the junctions of the tributaries, and raised between them, or along the basin fronts. A diagram of the high water of 1882 and low water of 1883, Fig. 2, shows that these differences in annual oscillation were caused, not by the rise, but by the excess of fall at the tributaries over that on the bars of the elevated bed of the river between them.

It was further indicated by the discharge observations taken at high waters, at the places near the tributaries, and at the others along the basin fronts, that the discharges at the former were about 1 500 000 cu. ft. per second, and exceeded those at the latter, or intermediate points along the basin fronts, by several hundred thousand feet.

This difference, from a quarter to a half million feet at times, had escaped from the river bed, over the banks, into the basins, and was returned to the main river below through the tributaries which are the outfalls for their normal and overflow drainage. Where the river discharged between banks the entire flood volume, the bed was deepened; and where it discharged only two-thirds of that volume, the bed was shallowed. The depletion of a thousand floods by overflow had impressed this shape upon the bed.

A part of the "Levee Theory" is that the escape of flood water from the river along the fronts into the adjacent basins caused the elevation of bed that existed, as evidenced by the low-water slope; and that, when this is prevented by levees, and the discharge confined, a primary effect will be the reproduction, in the high-water slope, of those elevations which have been observed and described in the low. This has already been brought about by the extension and improvement of levees, and is measured by the excessive height of recent

floods at points situated along the middle of basin fronts, as Memphis, or Lake Providence. It will be observed that an equal increase of heights has not occurred at the mouths of the tributaries. Mr. Harrod.

Another part of the "Levee Theory" is that a reversal, or removal, of the conditions which have contracted one part of the waterway and relatively enlarged another, of the same river, will remove these differentiations, and that with a uniform discharge for each stage, from Cairo to the sea, affected only by increment from the normal drainage of the basins, through an erosible bed which the river has moulded to its needs, these irregularities of slope, velocity and section will disappear, and that there will result a regular and substantially parallel slope curve, flattened a little by each increment of volume from a tributary, until Red River is reached, and from thence down the slopes at all stages will converge to sea level.

If the flow is as great along the basin fronts as at the tributaries, why should not the channel capacity of this strictly sedimentary stream be as great at one place as at another?

The condition in which the Commission found the river, and of which a description has been attempted, is the result of many centuries of alternation of channel depletion and enlargement at every flood stage. It is not to be expected that an accumulation of deposit, almost geological in its age and its mass, will be removed by five or ten years of levee improvement, or by a few great floods occurring at intervals of five or six years. But, with the force and time we have on hand the result is not in doubt. The evidence of a start in this direction is given in a previous part of this discussion.

The result of all observations seems to show a general tendency to an enlargement of the stream, that its capacity for flood discharge has been more than maintained, and that the apprehension of its deterioration, from natural causes, or from levee building, may be dismissed as, at least, unproved, if not disproved.

Consideration must also be given to the floods of the future, which will seek an outfall through the channel below Cairo. Will they be of greater volume than those of the past? They come from four sources, the Upper Mississippi, the Ohio and the Missouri water-sheds, and from the tributaries of the main trunk below Cairo. It may generally be stated that, when the first three form a combination which causes a dangerous stage on the Lower Mississippi, about two-thirds of the discharge, or 1 000 000 cu. ft. per second, is contributed by the Ohio. This is the controlling factor in great floods.

While the relation between deforesting and precipitation is assumed rather than established, there is no doubt that the processes of clearing, draining and cultivating may materially affect the distribution of the run-off, delivering to the streams of outfall a larger share in a shorter time, and tending to higher high waters and lower low waters.

Mr. Harrod. Under certain topographic conditions, these results may be limited and even reversed. It is, therefore, an important part of this discussion to consider the bearing which the conditions of the four sources of supply have had, and will have, upon the high waters of the Lower Mississippi.

It seems probable that the future changes in the flood conditions in the Upper Mississippi Basin will be slight. The forests, or those having commercial value, have been very largely cut down. cultivation under improved methods is already greatly extended, the reservoir system may be increased, and while the projected discharge of the Chicago Canal, constituting about one-tenth of the low-water discharge of the river below Cairo may be appreciably beneficial to low-water navigation, its contribution of about one-half of 1% to the flood volume is too small for consideration.

It is unfortunate that the records do not extend far enough back to give a life history of these tributary rivers, the gauges having generally been established within the last thirty years. Fortunately, since it bears on the most important flood factor, Cincinnati is an exception, having a continuous record of forty-five years. An examination of this shows that, if this period is divided in halves, the average of flood heights on the Ohio in the first half is 48.80, and in the second 52.37 ft. If, however, it is divided into thirds, they give the following relation of averages for the three periods: 48.51, 52.57, and 50.69 ft. For low water, the average result for half periods is 3.80 and 3.86 ft., and for thirds is 3.83, 3.60 and 4.06 ft. It does not appear, therefore, that on the Ohio River, for the last forty-five years, there has been a progressive change to higher high waters and lower low waters (although the processes to which such a result is usually attributed have presumably continued), but rather that some conservative or restorative influence has been in operation.

The high and low waters at Cincinnati for the period under consideration are shown in Fig. 3.

The physical conditions in the Basin of the Missouri are materially different from those in the Ohio. Except about the headwaters, it is a region of gentler slopes, largely without forests. Its progressive occupation and cultivation will be accompanied by plowing and planting surfaces which are now smooth and barren, and probably by a great development of reservoir building for irrigation. The tendency of these processes should be to check the rapidity with which its floods are discharged, and render less likely their coincidence with those of the Ohio, which generally culminate in February or March.

The tributaries below Cairo may be grouped together for consideration. While some of them head in arid regions similar to those drained by the Missouri, they generally flow through flat alluvial lands, where drainage is and always will be slow, and where the prevailing

forests will be gradually replaced by a cultivation which will not materially hasten the run-off. With overflow excluded from the basins, there is no reason apparent why the natural discharge of these drainage systems should be materially increased in the future.

If not levees, what then? Reservoirs, or Outlets?

The tendency of any extension of a reservoir system on the Upper Mississippi or Missouri would be to abate floods on the Lower Mississippi, but probably to a degree hardly appreciable. Such a system on the Ohio, if practicable, might produce more important results. But the late Milnor Roberts, Past-President, Am. Soc. C. E., closed this part of the subject forever in his most able report of 1870.

Outlets have received theoretic support in the report of Humphreys and Abbott, and of the United States Commission of Engineers of 1875 for the reclamation of the alluvial basin from overflow, but, after a detailed examination, they are unanimously:

"Forced unwillingly to the conclusion, that no assistance in reclaiming the alluvial region from

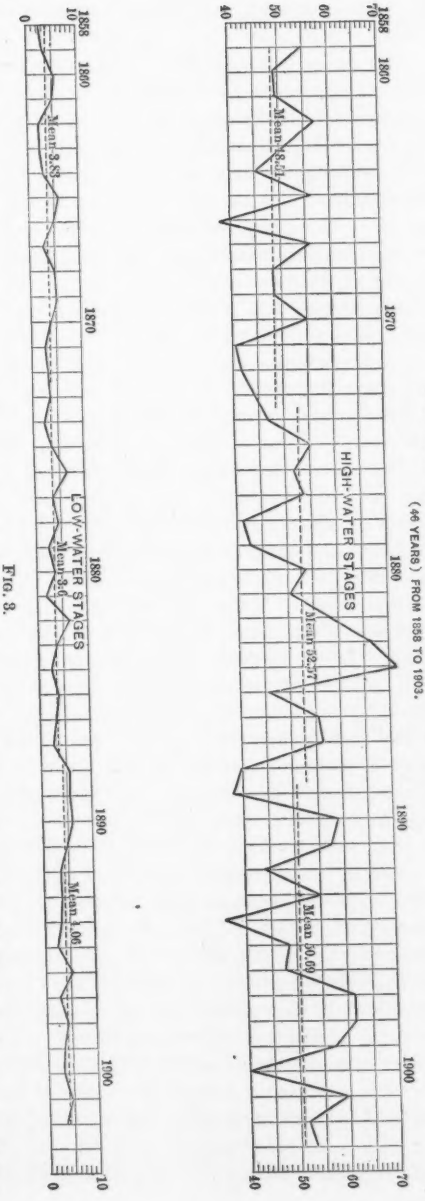


FIG. 8.

Mr. Harrod. overflow can judiciously be anticipated from artificial outlets. They are correct in theory, but no advantageous sites for their construction exist."

The views on which these theoretical conclusions in favor of outlets were based, *viz.*, that the bed of the stream was in a material so inerosible, and that changes in volume and velocity bore so little relation to scour or deposit, that its shape and dimensions would not respond to these changes, have not been upheld by more recent and exhaustive observations. These show that the bed is in a material which is being moved by the current from day to day and from bar to bar, and that its shape and dimensions are the resultants of this force.

The experience in levee building is that the limit to which the use of the material and methods of their construction can be safely extended has not yet been approached. The larger levees, which reach, in sloughs or other depressions, a height of 30 to 40 ft., and even more, are generally considered as among the safest.

Many substitutes and reinforcements for the earthen embankment, of various materials and construction, wood, stone, steel, concrete, etc., have been proposed. But when all things are considered, including ease of construction, economy and endurance, the outlook at present is that a carefully constructed earthen levee system, with sufficient grade and section, when properly cared for, presents advantages with which competition will always be extremely difficult.

There are two natural conditions prevailing on the Mississippi below Cairo which add materially to the practicability and efficiency of the "Levee System." One is the general presence of Bermuda grass, which grows with closely interwoven stems, attached to the ground by root tufts at close intervals, and forms a dense sod, presenting great protection against wave wash. The other is the high charge of sediment carried by the river at its higher stages. As the water seeps into and through the levees, it is filtered, the particles being deposited in the interstices of the soil of which it is built. The clear water percolates through to the land slope, while its charge of sediment remains and gradually diminishes the leakage.

The experience concerning the cost of making good the losses sustained by the existing levees, from caving banks and breaks from other causes, has been collated for the past eight years. It amounts annually, during that period, to a little less than 1½ per cent. The losses by the flood of this season and by certain important works of renewal now in sight will probably temporarily increase this annual cost in the near future. Also, as the levees approach the grade and section which it is considered necessary to give them, and their contents per linear foot is thus increased, the work of closing any gap that may occur will be proportionately greater. On the other hand, the better locations, construction and care which are already made possible, to

a certain degree, and which can, in the future, be practiced to a still greater extent, from the more liberal and regular supply of funds, should tend to a reduction of the annual losses from caving banks, and the occasional losses from extreme high waters. Mr. Harrod.

This increase of resources can be expected both from a fuller realization by the General Government of the importance of the work which it has undertaken, the reclamation from overflow, and the agricultural and commercial development of 20 000 000 acres of the most fertile soil, and from the increasing number and wealth of the communities now occupying and improving these lands.

The amount applied to the extension and improvement of the levee system of the Lower Mississippi in the year 1900 was about $2 961 000. Of this, about $1 000 000 was allotted from the appropriation by Congress for the river below Cairo, and the balance was supplied by the levee organizations of the riparian States. This is, substantially, the division of cost which has prevailed since the Government has shared in the construction of a levee system. Several of these local organizations now feel justified, by their experience with the "Levee Theory" to seek legislative authority for an increase of their contribution by additional taxation and bond issues.

When the levee system of the Lower Mississippi shall have been completed, it will still be but an engineering structure, subject to the vicissitudes of time and accident. It will need constant care, and occasional renewal of parts. Crevasses will occur as long as trains are derailed, or collide, as ships are wrecked, or fire-proof buildings are destroyed. A crevasse in the levee of the future will be a more serious disaster than in one of the present time, in proportion to its greater depth and discharge, and the greater improvements which have developed under its protection. But this is the case with all of our work, whose progress has not been deterred by the greater risks which are necessarily assumed in meeting the demands of modern civilization.

This discussion, already too long, will be closed with a short comparison of the floods of 1897 and 1903 and their results.

The computations of the discharge measurements of the last flood are not yet complete, but it is apparent that the maximum discharge of 1897 was slightly more than that of 1903. Greater heights were generally reached this year, mainly along the fronts of the basins where levees have made the greatest reduction in the overflow, but not at the mouths of the tributaries. This increased height was due both to the extension of levees along hitherto unleveed fronts, and to the improvement made in the existing lines since 1897, which enabled them to exert more resistance and control.

The greatest increase of flood height this year was about 3 ft. at Memphis, where levees have been but recently extended. Nevertheless, there were, in 1897, between Cairo and New Orleans, a distance of

Mr. Harrod. 960 miles, forty-three crevasses, while during the past flood, so great had been the improvement of levees in the meantime, there were but six. While the limit of the overflowed area has not yet been completely ascertained, it is known to be reduced largely, if not quite in proportion to the lesser number of breaks.

Table No. 4 gives certain high-water records. In the third column is given a standard, adopted provisionally as the heights which great floods might be expected to reach when controlled by levees. The other columns are explained sufficiently by their headings.

The experience of 1903 makes advisable a revision of the provisional standard in the vicinity of some of the gauge stations.

TABLE No. 4.—HIGH-WATER RECORDS.

Gauges.	Miles below Cairo.	Standard high-water.	Highest before 1903.	Highest in 1903.	1903 compared with previous highest.	1903 compared with standard.
	Miles.	Feet.	Feet.	Feet.	Feet.	Feet.
Cairo	.....	54.17	52.17	50.60	—1.57	—3.57
Columbus	21.3	48.10	45.58	44.40	—1.18	—3.70
New Madrid	70.3	42.90	41.50	39.50	—2.00	—3.40
Cottonwood Point	122.5	42.20	39.35	40.00	+0.65	—2.20
Fulton	175.4	40.40	38.30	40.10	+1.80	—0.30
Memphis	230.0	41.60	37.66	40.60	+3.00	—1.00
Mhoon	276.3	46.20	41.60	41.80	+0.20	—4.40
Helena	306.5	54.10	51.75	51.00	—0.75	—3.10
Sunflower	352.7	50.20	47.17	48.00	+0.83	—2.20
White River	393.2	56.40	52.42	53.70	+1.28	—2.70
Arkansas City	438.3	56.30	51.90	53.00	+1.10	—3.30
Greenville	478.3	50.50	46.75	49.10	+2.35	—1.40
Lake Providence	542.3	48.00	44.54	46.40	+1.86	—1.60
Vicksburg	599.3	55.00	52.48	51.80	—0.68	—3.20
St. Joseph	648.3	50.80	47.85	48.00	+0.15	—2.80
Natchez	700.3	54.00	49.82	50.40	+0.58	—3.60
Red River Landing	765.3	52.50	50.20	50.00	—0.20	—2.50
Bayou Sara	799.8	45.70	43.70	43.45	—0.30	—2.30
Baton Rouge	833.3	43.20	40.65	40.00	—0.65	—3.20
Plaquemine	854.1	38.70	36.25	36.19	—0.15	—2.60
Donaldsonville	885.4	34.95	32.75	32.20	—0.55	—2.75
College Point	904.5	29.80	27.95	27.80	—0.15	—2.00
Carrollton	957.0	20.35	19.17	19.40	+0.23	—0.95
Fort Jackson	1 039.0	8.00	7.20	8.00	+0.80	—0.00

It will be observed that no high water has yet reached the predicted standard.

The engineers engaged in the reclamation of the Valley of the Mississippi River from overflow know more about levee building than they have yet had the opportunity of putting in practice. They are quite aware of many and much-needed improvements, both in their construction and in their care and preservation. Up to the present time, the compelling need has been, and for several years will be, continuity of line, higher grades and standard sections. Those used provisionally are everywhere below those considered safe for great floods, and the

present contents of levees are not more than 60% of what is considered necessary for satisfactory protection. Mr. Harrod.

Yet, behind this partial shelter, population has increased, values have risen, wealth has accumulated, comfort and culture have developed, and great railroad systems have extended, at such a rate that it can be said that the reclamation of this region is one of the most successful and beneficent public works now in progress.

L. W. Brown, M. Am. Soc. C. E. (by letter).—A quotation from Bayard Taylor's ode to the Nile applies very appropriately to the Mississippi River: Mr. Brown.

> "Mysterious Flood,—that through the silent sands
> Hast wandered, century on century,
> Watering the length of great Egyptian lands,
> Which were not, but for thee."

The Mississippi River, from its mouth to the head waters of the Missouri, has a length of 4 190 miles, and is, perhaps, the longest river in the world. The navigable waters of this great river and tributaries are estimated as having an aggregate length of more than 15 000 miles.

The river drains an area embracing 56° of longitude, and 21° of latitude, aggregating 1 240 050 sq. miles; or 41% of the whole area of the United States, exclusive of Alaska.

Were it not for this great river, the main trunk of which flows through the very core of our country, we would not have the vast area of rich alluvial lands which constitute, not only a large portion of our country, but a most productive and valuable portion; and we would not have, as a subject for discussion, the protection of this valuable territory from the ravages of inundation.

Referring to the observations of Taylor on the Nile, the first thought is that this large and valuable section of our country was made by the Mississippi River according to the well-known and established laws of Nature; and the further thought is suggested, would civilization, had it existed during the period when this system of making a country was inaugurated by Nature, have allowed it to be done.

If an answer were to be made in accordance with the methods adopted by man in all his works, thus far, in connection with the Mississippi, it would, of necessity, be in the negative, and, as a consequence, we would to-day have no valuable and extensive territory to protect.

It is perhaps a most wise provision of Nature, that her large and extensive undertaking, in making a rich and productive country, was inaugurated, and nearly completed, before civilization was introduced, otherwise we might now be compelled to live and have our habitations in floating craft, in order that all the available land could be utilized for agricultural purposes to support us until we could complete the filling of the deep seas and oceans, which we are now straining every energy to accomplish.

Mr. Brown. When man first settled in this rich alluvial territory, about 185 years ago, he immediately began the construction of levees, and thus was inaugurated the principle which has been extended and enlarged until the whole length of the river is now provided with a range of mountains on each side, almost completely confining the waters; and the old-fashioned method of building a country, adopted by Dame Nature centuries ago, has been entirely discontinued; and this method of Nature's, like the fashion of dress worn by our forefathers, is, in this enlightened age, considered out of date.

That levees are necessary for the proper protection of the alluvial territory from inundation from the river admits of no argument. They are absolutely necessary; but, the protection of the territory, by confining the entire volume in the main trunk, in order to improve navigation, is most apparently disastrous to both protection and navigation, and it is reasonable to assume that we must either abandon our present methods of protection, in attempting to confine all the flood volume in one main trunk, or be satisfied to lose eventually, not only the money and energy expended in the work, but also all the benefits of our large and valuable alluvial territory, as Nature will not long submit to being "straight-laced and corseted."

Voltaire says: "The progress of rivers to the ocean is not so rapid as that of man to err."

It is well within the line of possibility, considering the past and existing conditions as regards the Mississippi floods, that man has erred, and erred sadly, in attempting to interfere with Nature's laws, as he has no doubt done, in an endeavor to confine the whole flood volume in one main trunk, and not allow the low places to be elevated and the swamps reclaimed for the support, health and prosperity of future generations.

It would appear to be unnecessary, in the light of the information now available, and of the facts now demonstrated, to detail the many reasons why the total confining of the waters of the Mississippi would not be disastrous to all interests, not only for the present, but for all future generations.

The very fact that we are neglecting an opportunity to build up the low places, reclaim swamp areas, and thereby improve the health of the territory, is sufficient evidence that we are not making a proper use of Nature's gifts; and it is possible that our efforts to confine the floods are a violation of Nature's laws.

The futility of attempting to confine the flood waters of the Mississippi is demonstrated most thoroughly and convincingly by a consideration of the work executed during the past twenty-five years, and the results secured.

Prior to the appointment of the Mississippi River Commission by the Federal Government, in 1878—twenty-five years ago—no general

or systemized plan for leveeing the river was attempted. Each State constructed levees, for protection only, on such lines and such locations as best served their several interests. At this time, or prior, there was no thought of confining the whole volume of floods. Mr. Brown.

Since 1878, a combined effort, requiring the expenditure of a very large amount of money and energy, has been made by the United States Government, the States and Parishes, and by the individual interests bordering on the stream, to make a continuous levee system throughout the whole length of the river, and to retain entirely the flood waters within the trunk of the river, and not allow the low places and the swamps, which comprise a very large area, to assist in lowering the flood plane.

This system of levee construction was inaugurated 185 years ago, but only during the past few years has it reached such a stage of completion that its effects could be observed impartially and practically, and determined with reasonable precision; and, while the system is still far from completion, we have now a clear and positive conception of the utter futility of securing from the further completion of the system any reasonable or satisfactory results.

The ultimate disastrous results of the attempt to confine the flood waters of the Mississippi (aside from the tremendous losses from inundation, which are known and apparent to all) are most eloquently portrayed by a close observation of the flood condition during the time when but a very small amount of the work, forming the principle of the present system, was completed, as compared with the past few years when the system has been extended very considerably.

Comparing the flood heights at Carrollton, La., we find that the great flood of 1828 reached an elevation of 14.85 ft. above sea level. The great flood of 1851 reached an elevation of 15.05 ft. above sea level, or 0.2 ft. higher than the flood of 1828. The great flood of 1874 reached an elevation of 15.35 ft. above sea level, or 0.3 ft. above the flood of 1851, or 0.5 ft. above the flood of 1828. The great flood of 1897 reached an elevation of 18.72 ft. above sea level, or 3.37 ft. higher than the flood of 1874, or 3.67 ft. higher than that of 1851, or 3.87 ft. higher than that of 1828. The flood of 1903 reached an elevation of 19.05 ft. above sea level, or 0.33 ft. higher than the flood of 1897, 3.70 ft. higher than the flood of 1874, 4.0 ft. higher than the flood of 1851, and 4.2 ft. higher than the flood of 1828.

It is instructive to observe:

1st —That during the twenty-three years, from 1828 to 1851, the increase of flood plane was only 0.2 ft., and that during this period of twenty-three years very little protection work was executed.

2d.—That during the twenty-three years from 1851 to 1874 the increase of flood plane was only 0.3 ft., and that during this period of twenty-three years considerable protection work was executed, but it

Mr. Brown. was small as compared with that of the following period of twenty-three years.

3d.—That during the twenty-three years from 1874 to 1897 the increase of flood plane was 3.37 ft. It was during this period of twenty-three years, beginning in 1878, that great activity was displayed in the construction of levees, and in 1897 these levees confined a very considerable portion of the river.

4th.—That in the short period of six years—1897 to 1903—the increase of flood plane was 0.33 ft. During this period of six years the levee system was considerably enlarged, strengthened and extended, but was far from being completed.

5th.—That in 1828 there was practically no protection work.

6th.—That in 1851 and 1874, the protection works were very limited, both as to extent and dimensions.

7th.—That in 1897 and 1903 the protection works were very large, both in extent and dimensions.

8th.—That in none of these years of high floods have the protection works been maintained against failure.

9th.—That we have no method of determining positively what would have been the elevation of the floods, or other conditions, had the protection works not failed.

10th.—That there is no known or proven formula, guide, rule, or precedent by which works of protection, which embrace the confining of the flood waters, can be calculated, designed or constructed with any degree of safety.

11th.—That we have no absolute or positive evidence that the meteorological and climatic conditions during these years of high floods were abnormal, or that these conditions, if abnormal, during these years, will not be surpassed in their intensity to precipitate floods in the future.*

12th.—That the elevation of normal high water in later years, or from 1897, has reached a higher elevation above sea level than did the great flood of 1874 or of those previous to 1874.

The foregoing cursory examination of flood conditions, covering a period of seventy-five years, provides convincing arguments which show most conclusively that we may not, with entire economy or safety, confine the flood waters of the Mississippi; and there exist other arguments and reasons, equally convincing and tenable, which will be referred to briefly as follows:

A.—The present status of the material forming the alluvial basin through which the river runs, is such that even with low velocity, a uniform, constant and proper waterway or channel cannot be maintained, as is possible in older and more stable territory; and, as a con-

* The extraordinary floods in Kansas, Nebraska and Iowa, during the past few days, or since this discussion was prepared, demonstrate most emphatically the correctness of the views herewith presented, especially in reference to future floods.

sequence, there would be no assurance, even if the volume of a flood could be calculated and known, that the trunk would receive and discharge it safely and properly, as the discharging capacity of the river at a given elevation of flood plane, is, and will so remain for centuries to come, an absolutely unknown quantity—never the same for two seasons in succession—due to the constant changing of bed, and other conditions. Hence the successful confining of the floods within the trunk is scarcely within the line of a possibility. Mr. Brown.

B.—The high velocity required to discharge the large flood volumes, if confined in the main trunk of a river which flows through a new formation such as that comprising the Mississippi alluvial, would be such as to abrade constantly the high banks which Nature built originally, and carry them to the sea, and thus not only destroy what Nature accomplished for the benefit of man, but require the reconstruction of levees, upon lower, newer and less stable ground, which would not only increase the cost largely, but increase very largely the danger of their failure.

C.—The confining of the floods of the Mississippi will, in time, result in the decrease of the cross-section now existing below the natural bank, and, with the same volume of discharge, will raise the elevation of the flood plane. This statement is made with the writer's full and positive belief that the increase of velocity necessary to discharge the confined flood volumes of a stream flowing in alluvial territory, and which tears down banks and builds shoals in a heretofore deep pool or reach, must, of necessity, gradually but surely shoal the bottom and foul the sides, thus decreasing the original cross-section. This statement and belief is substantiated by the history of alluvial rivers in older countries, and is also verified by an examination of the cross-section of the river at Carrollton for a period covering seventy years.

Table No. 5 is constructed to show that in seventy years the cross-section below the natural bank at Carrollton has decreased.

TABLE No. 5.

Flood year.	Elevation above sea level, in feet.	Velocity, in feet per second.	Discharge, in cubic feet per second.	Cross-section, in square feet.	Height above flood of 1828, in feet.	Area above flood plane of 1828, in square feet.	Area below flood plane of 1828, in square feet.	Area fouled since 1828, in square feet.
1828	14.85	5.90	1 099 000	186 271	0	0	186 271	0
1851	15.05	5.99	1 118 000	186 644	0.2	580	186 064	207
1874	15.35	6.75	1 175 000	174 074	0.5	1 450	172 624	13 647
1897	18.72	7.30	1 350 000	184 800	3.87	11 223	173 577	12 694
1898	15.30	6.28	1 084 000	172 611	0.45	1 305	171 306	14 965

Mr. Brown. The discharge data for 1903, when it is received, will no doubt furnish very interesting additional information.

It will be observed that the cross-section below the flood plane of 1828 was 207 sq. ft. less than in 1851; the section in 1874 was 13.647 sq. ft. less than in 1828; in 1897 it was 12.694 sq. ft. less; and in 1898—normal flood—14.965 sq. ft. less.

The discharge data for 1896, if obtainable, would be very interesting to show what scour was occasioned by the high velocities of 1897—which velocities, as recorded by scientific investigation, were sufficient to abrade stratified rock—and it is somewhat surprising that the high velocities of the flood of 1897 did not recover the section as it existed in 1828. It will also be noted that the section below the flood plane of 1828 was, in 1898—a year of normal flood—2 271 sq. ft. less than in 1897.

The application of Kutter's formula for the discharge of streams shows that the floods of the Mississippi are not consistent under comparative conditions. The flood of 1851, which had a cross-section of 186 644 sq. ft. and a slope of 0.125 ft. per mile—by formula—would have a velocity of 6.22 ft. and a discharge of 1 160 926 cu. ft. The actual gauging of the stream was 5.99 ft. velocity and 1 118 000 cu. ft. discharge. The flood of 1897, when the area was 184 800 sq. ft. and the slope 0.156 ft. per mile—by formula—would have a velocity of 6.512 ft. and a discharge of 1 203 417 cu. ft. The actual gauging, however, shows 7.30 ft. velocity and 1 350 000 cu. ft. discharge.

D.—Our country, to-day, is rich, prosperous and powerful, and can, perchance, by great exertion, raise the necessary funds to construct and maintain these very large and expensive levee lines, to confine the river (but it can never be accomplished and absolute safety assured); but in times of adversity, which every country may expect to experience, and funds are lacking to maintain them properly, what will become of this great levee system, which requires constant watching, guarding, and the annual expenditure of large sums of money? And if the levee system, when constructed, if it were possible, to the acme of success, as far as confining the flood waters is concerned, is by necessity forced to be neglected, what becomes of our rich alluvial country?

Works affecting such enormous values, as do the works of protection against inundation by the floods of the Mississippi, must, of necessity, to be worthy of adoption, be such as will not confiscate the country in their construction; and also such as will serve reasonably well the purpose for which they were constructed, were they, from expediency, forced to be neglected for a time.

E.—In time of war, the levee system of the Mississippi, if it could be constructed to confine ultimately the flood volumes, would be of national and international importance as an engine of warfare, and its

control would be contested hotly. To the country owning it it would present an ever-abiding menace, for should an enemy obtain control, for a few hours only, of any part of the territory embracing the system, a very powerful and readily-operated weapon would be secured, as with great dispatch, effectiveness, and at the least possible cost, a whole country could be submerged and devastated, and the operations of a whole army be practically stopped. Mr. Brown.

F.—The continuation of the present system, and the attempt to confine the flood waters of the river, will require the construction, in the very near future, of levees of enormous proportions, which will be a very heavy burden on the whole country as well as on the alluvial territory, and no positive or lasting good will be secured. And it would appear that, before proceeding further with the undertaking, a very careful consideration should be given the matter, and an endeavor made to secure, if possible, some less expensive, more satisfactory and efficient method of protecting this valuable section, as also one which will conform better to Nature's laws, and secure for posterity all the advantages and benefits possible.

The problem presented is apparently most intricate from every point of view, and will, perhaps, require most careful and searching investigation and study; but the solution should not be delayed, as the settling up and improving of the territory presents additional complication and trouble, and the quicker we determine upon the proper method to be adopted, the better for all present and future interests.

It is apparent, however, that the intricacies of the solution of the problem lie more in the detail than in the general principle of a system which will accomplish the desired results properly and satisfactorily. By a consideration of the topographical conditions of the territory, in conjunction with what is reasonable to assume would be Nature's methods in handling the problem, if not interfered with by the work of man, together with the experiences, data, and facts secured during the past seventy-five years, a very clear and positive general principle is descried.

Referring to the topography of the territory, it will be observed that the main trunk of the Mississippi, from the mouth of the Ohio to Memphis, is located on the extreme easterly edge of the alluvial embayment, directly against the high bluff territory of a former geological age, and has a general direction almost due south. It will also be observed that, from Memphis, the trunk leaves the higher and older territory and runs southwest diagonally across the alluvial to Arkansas City, when it assumes a southeasterly direction and recrosses the alluvial on a diagonal from Arkansas City to Vicksburg, where it again strikes the higher and older country, on the extreme east of the alluvial.

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Mr. Brown. From Vicksburg to Natchez the river runs southwest; from Natchez to the mouth of the Red River, the direction is about due south; and, from the mouth of the Red River to Plaquemine, the direction is southwest. The trunk of the river, from Vicksburg to Plaquemine, hugs the higher and older country lying to the extreme east of the alluvial. From Plaquemine to New Orleans the general direction is but a little south of east, and between these points the trunk keeps well to the north of the alluvial territory as it exists to-day, paralleling the southern limits of the higher and older territory. From New Orleans to the sea the general direction is southeast, and directly through the alluvial.

It will be observed that the river hugs the high country on the east side of the alluvial embayment throughout its whole length, from the mouth of the Ohio to near New Orleans, excepting between Memphis and Vicksburg, and that the tendency of the river throughout is to hug or parallel this higher or older territory on the east.

The older geological formation on the east of the alluvial is much higher and more abrupt, where it meets the alluvial, than is this older territory on the west; hence the tributaries entering the trunk from the east have sufficient velocity and abrading force to cut a waterway through the alluvial banks of the trunk; and the formation of the older territory has more resistance against abrasion than the alluvial, and hence provides a waterway of more stability. A further cause is due to the fact that the sediment of an alluvial stream which deposits and raises the banks and the surrounding country on both sides of the stream will in time provide a cause for the change of the bed or trunk of the stream by the abrading and tearing down of the banks on that side of the stream which receives tributaries which have sufficient power to abrade and tear down, as, for the reasons mentioned, the tributaries from the east no doubt have.

That at a former period of time the trunk of the Mississippi was far to the west of its existing location is shown clearly by the existence of the high ridges lying between the western edge of the alluvial embayment and the present trunk, or, perhaps, there were at times several well-defined trunks.

The existing topography would indicate clearly that at one time the Red River discharged into the sea, perhaps, as far west as Cote Blanche Bay; and when we consider that the westerly and southerly banks of the streams—whether one or more—which existed previously in the alluvial territory were subjected to less abrasion and wear from tributaries than were the easterly and northerly banks, the cause for the present location of the trunk is clearly shown.

Had the alluvial basin of the Mississippi not been inhabited for centuries to come, and had Nature been allowed to finish the work in her own way, there is no doubt that eventually there would have been

two large separate and distinct rivers, extending from about Cape Girardeau—or from a point above the mouth of the Ohio—to the sea; one directly adjacent to the old and high territory on the extreme east and north of the alluvial embayment, which could receive and deliver to the sea all the waters from the eastern tributaries, and one on the extreme west of the embayment, receiving and discharging all the waters from the western tributaries. Mr. Brown.

The process of the formation of these rivers would be that the trunk as now existing would be gradually moved, by the constant abrasion and tearing down of deposits on the eastern and northern banks by the tributaries from the east, until it occupied a position directly against the higher, older and more stable formation forming the eastern and northern boundary of the alluvial; and the trunk, from Memphis to Vicksburg, would probably pass in the neighborhood of the present towns of Charleston, Greenwood and Yazoo City, in the State of Mississippi; and, from below Baton Rouge, the river would flow through Lakes Marapau and Pontchartrain and discharge into Mississippi Sound through the territory between the Rigolets and Chef-Menteur.

The length of the river by this route, from Baton Rouge to Mississippi Sound—tide water—would be about 95 miles. From Baton Rouge to the sea by the present trunk is 220 miles, or 125 miles further than the route which Nature no doubt proposed to adopt ultimately.

When this eastern main trunk had become permanently located directly against the older and more stable formation on the east; and the west bank of the stream had become in time sufficiently elevated, from the annual deposits of an alluvial river, to exclude the waters from the west, these waters from the west would seek and cut a channel in the alluvial on the west of the main trunk, and begin to discharge directly to the sea, entirely independent of the main trunk located adjacent to the eastern shore of the alluvial; and this independent stream, conveying the waters from the west to the sea, would be moved westward gradually until it occupied a location directly adjacent to the older lands on the western edge of the alluvial.

The process of moving this second stream, and the cause, would be the same as that which had moved the trunk to the extreme eastern limit of the alluvial. The western bank of the second stream would be constantly torn and abraded by the waters from the western tributaries, and the ultimate delta of this second river connecting with sea would no doubt be as far west as the western limit of the alluvial embayment—about at Cote Blanche Bay.

The alluvial territory between these two streams, at the time when they were ultimately developed, would be well filled, and high, with lakes and drainage branches and a drain directly to the sea entirely independent of the two main rivers.

Mr. Brown.

The study of the subject, on the basis of carrying out practically the principle adopted by Nature, with such modifications as will reasonably meet the conditions of the alluvial as they now exist, would perhaps develop a measure by which the low swamp regions of the territory would be utilized by connecting them, where necessary, by cutting through the ridges, and thus provide a secondary stream to carry the surplus water direct to the sea.

The high land surrounding these low swamp places could be protected by levees, and this secondary stream could extend from near the junction of the Ohio to the sea, the main trunk of the river being arranged so as to deliver all flow above a certain stage direct into this secondary stream.

Assuming that the future floods will aggregate a maximum flow of 1 500 000 cu. ft. per second, it is reasonable to assume that the main trunk will discharge, for a century to come, without any large additional improvement, 900 000 cu. ft. per second, at a flood elevation not exceeding that of 1874. The maximum volume to be delivered by this secondary stream would be 600 000 cu. ft. per second; and if this stream were two miles wide, with an average depth of 9 ft., it would discharge this volume with a velocity of about 6 ft.

This secondary stream, to embrace the full area of the low swamp territory, would have an average width largely exceeding two miles, and the width through the ridges would be made to suit the conditions.

Cross-levees, forming reservoirs, could be constructed where desired, and outlets from the stream, to reservoirs on either side, could be constructed as might be found expedient. An opportunity would thus be offered for the retention of as much water as might be desired for industrial and agricultural purposes, and the swamps would be gradually filled. The volumes retained in this secondary stream as a reservoir, and in the special reservoirs, would reduce materially this maximum aggregate volume of 600 000 cu. ft. per second.

To describe the measure in more detail, yet in a general way, it is suggested to provide a secondary stream by leveeing in all the swamp territory lying west of the existing trunk, and extending from near Dog Tooth Bend, above Cairo, to a point near Helena. This swamp embraces the Hatchie Coon sunken lands, Roaring River and St. Frances Lake. The secondary stream should be connected with the river by suitable waste weirs, of proper proportions, near Dog Tooth Bend, and also at such other points as might be found necessary, as at New Madrid and Centennial Lake by cross-levees; which latter, as outlets, would admit of filling the extensive low swamp areas embracing Lake Nicormy, Big Lake and Tyronza Lake, when the adjacent high land was protected by levees.

This secondary river should enter the main trunk near Helena. From Helena, the secondary stream should be continued on the east side

of the main trunk from near Helena to near Vicksburg, through the low swamp lands embracing either the Big Sunflower or the Yazoo Rivers. The levees embracing these swamps should be located so as to protect properly all the adjacent high and improved territory. Mr. Brown.

From Vicksburg, the secondary stream should be continued on the west side of the main trunk, from a point near Vicksburg to the Red River, and would be formed by the leveeing of the large swamp areas embracing the Tensas and Black Rivers.

From the Red River to near New Orleans it is suggested to improve the trunk of the river so as to deliver an approximate maximum of 1 300 000 cu. ft. per second, for use in filling up the large areas of low swamp lands east of the Lafourche. The waste weir at the Red River should be constructed so as to deliver the surplus into the immense swamps bordering the Atchafalaya River. All the high land surrounding these swamps should be properly protected by levees, the surplus water finding its way to the sea over the extensive marsh bordering Atchafalaya Bay.

All the high lands bordering the large swamp areas east of the Lafourche, should be properly protected by levees, and these swamps connected with the main trunk of the river by a suitable waste weir.

A waste weir of proper proportions and construction should be located on the east bank of the river, near Grand View Reach, and connected by cross-levees with Lake Marapau.

The object of connecting the large swamps east of the Lafourche, and those surrounding Lake Marapau, would be to fill them gradually, and in course of time render them of value for cultivation.

The locations referred to in the foregoing outlined description are merely to serve as explanatory of the proposed system. The determination of the details, as to the location of relief works, or of the secondary stream, or of making this secondary stream entirely independent of the main trunk, instead of being connected as described, would be determined by the conditions developed from a thorough survey and investigation of the territory.

The drainage of the high and improved territory, under the conditions resulting from the method of protection outlined herein, would, of necessity, require to be artificial, which, as a matter of fact, where any proper drainage exists, is that under existing conditions.

The effective and economic construction of the levees to confine the waters in the swamps and low places, throughout the territory, would be by floating dipper dredges, which, in the formation of levees, would construct proper drainage canals to serve the adjacent high and improved territory, and provide proper and economical service to all interests. The drainage of the territory should be designed and operated by the same authority which controls the protection system, and thus be made part of the protection work.

The protection of the alluvial lands from inundation, by a system

Mr. Brown. which will relieve the main trunk of the excessively high flood planes and accompanying high velocities and other conditions which are detrimental to, and incongruous with, a permanent channel location, will improve most materially the navigation of the stream, and will admit of some reasonably satisfactory and efficient results being secured from the construction of works for that purpose. It will also admit of such works being maintained in position to serve the object for which they were constructed.

The construction of the levees on the main trunk of the river, on such lines as will admit of a more uniform cross-section for flood volumes than is now provided, and the clearing of all the batture areas, between levee lines, of trees and undergrowth, which interfere with the free flow of the water, and the maintaining of this water section free from obstructions, will increase the flood discharge, and also assist most materially in maintaining a permanent channel, which will thereby improve the navigation of the stream.

The momentous advantages sought to be secured are:

1st.—Reduction of the flood plane;

2d.—Reduction of the dimensions of levees;

3d.—Reduction of flood velocities in the main trunk;

4th.—The formation of a more stable bed for the main trunk, thereby avoiding the abrasion of the high banks;

5th.—The reduction of the fouling of the bottom and sides of the main trunk;

6th.—The maintenance of a reasonably permanent channel, thus improving the navigation of the stream;

7th.—The gradual filling of the swamps and low places;

8th.—The improvement of the health of the country;

9th.—The retention of all water necessary for industrial and agricultural purposes;

10th.—The economy and efficiency of all works constructed for the protection of the territory, and for the navigation of the river;

11th.—The positive protection of all the improved property against inundation.

When the subject of the protection of alluvial lands is forced upon the civil engineer by dire calamity, resulting from the failure of protection works, he is attracted by its great importance, and even in giving a passing thought to the subject, he is astonished and amazed. The consideration of the many combinations of varied conditions existing in the vast territory tributary to the Mississippi, coupled with probable future meteorological and climatic changes, and the consideration of the alluvial embayment as it was in times past, as it is in this age, and as it will be in future ages—or would have been had it not been inhabited—provides material for deep reflection, and causes man, even in this age of great engineering attainments, to pause before as-

suming a responsibility in connection with a work which will affect all future ages. Thus the very important question is presented: Shall the present system, confining all the flood waters in one trunk, which entails disastrous results to all present and future interests, be continued in opposition to Nature's laws; or shall our works of protection be modified so as to carry out the design of Nature in a reasonable way, thus securing the greatest possible benefit to all interests of this and of future ages? Mr. Brown.

J. A. Ockerson, M. Am. Soc. C. E. (by letter).—In early days, prior to the advent of the levee system, the steamboat-man and the passenger going down the Mississippi River saw a narrow strip of cultivated land along the immediate banks of the river. They did not realize that for forty to sixty miles beyond that strip the alluvial basin was practically uninhabited and its rich soil untilled. Mr. Ockerson.

They saw the fields covered with water during flood times, to a depth of perhaps 3 or 4 ft., and very limited areas in certain localities, developed by radical changes in the regimen of the river, were known to be above water except during extraordinary floods. They did not appreciate the fact that perhaps five miles farther back the water was 10 ft., or more, in depth; that, without levees to control the floods, these great interior basins could not be inhabited or cultivated.

In the meantime systematic levee work began, and, year by year, the levees are gradually being brought up to such height as will finally effectually carry the greatest floods safely to the sea. These same men notice that the flood water, on the battures and the lands between the levees, gradually becomes deeper and the levees grow higher, and they conclude that if the levees can ever be made to control the floods at all they will ultimately "reach the tree tops in height." They are fully convinced and most positive in their opinion that the increase in flood height is due to the raising of the river bed.

To the engineer, it is no surprise that there should be an increase in the height of a flood confined between levees from one to five miles apart over that of a flood confined only by the hills that limit the basins with a width of forty to sixty miles. More than that, the engineer, in the beginning of the work, computed the heights which the maximum confined flood would ultimately reach, and the results have shown that his calculations are very near the mark.

Everyone familiar, even to a slight degree, with the physical characteristics of the river, has noticed the extraordinary local changes that occur in brief intervals of time. Very few, however, realize the fact that tangible changes in the general regimen of the river require long periods of time.

The belief, among laymen, that there is a general progressive elevation of the bed of the stream going on, which is augmented by levees, is widespread. Statements have been made, by those who ought to

Mr. Ockerson. know better, that the bed of the river at New Orleans is higher than the adjacent land, while the fact is, that the bed is some 200 ft. below the land.

A former Secretary of War, in discussing this question with the writer, stated that he proposed to settle the vexing question himself by "measuring the river in several places." Just what he intended to compare the measurements with or how he proposed to eliminate the effect of purely local changes, does not appear.

The statement that the Mississippi River Commission had already made many thousands of such measurements, covering some 425 miles of river, may have had something to do with the abandonment of his project.

Without any preconceived theory to prove, and with a view of simply ascertaining the facts in the case, the writer prepared in 1894 a project for a resurvey of the river from the mouth of the Arkansas River to Donaldsonville—a distance of 425 miles—and this project was approved by the Mississippi River Commission.

The first general survey had been made, much of it under the personal supervision of the writer, some twelve to fifteen years prior to that time. This first survey comprised accurate lines of levels, with established bench-marks at intervals of three miles. Each line of soundings across the river (at frequent intervals), had its water-surface elevation determined by levels, hence an accurate cross-section of the bed could be plotted. Surveys made at the later date, referred to the same bench-marks and the same datum, gave reliable data from which to determine the difference in conditions at the two epochs.

A careful comparison of the two would, of course, disclose any general changes of considerable magnitude in the elevation or capacity of the bed.

The thousands of cross-sections of the two surveys were carefully plotted, their respective areas measured, and their mean and maximum depths determined. Then comparisons were made between individual sections and between corresponding groups of sections comprising successive pools and crossings. All this entailed an enormous amount of painstaking work, and the conclusions are as follows:

The crests of the low-water bars, as well as the high-water bars, were found to be lower. About half of the total length resurveyed showed a depression of the thalweg, and about an equal amount showed a slight elevation confined chiefly to the pools.

The results reached by this investigation are not as specific as might be desired, but it does not seem possible that such great elevations of bed as would be required to account for increased flood heights could escape detection.

Embracing, as it did, a comparison of 2 768 cross-sections of the

river, together with something like 150 000 elevations, it seems to prove beyond a reasonable doubt, if any such proof be really needed, that the elevation of a confined flood in the Mississippi is not due to the elevation of the bed of the river. Mr. Ockerson.

There is a still more simple proof which should be satisfactory to all, even if highly prejudiced against a levee system.

Gauges are established at intervals along the river, and are connected with several permanent bench-marks in the immediate vicinity. Frequent inspections keep the gauge zeros at the same height from year to year. The readings are taken by reliable observers, both morning and evening, and a continuous record is thus maintained throughout both high and low waters.

These records show in the most positive way that the low waters of recent years are several feet lower than those of earlier years with equal volume of flow and with equal channel depths.

Only one explanation of this condition is possible. It points unerringly to a depression of the bed of the stream, and should effectually set at rest any fears that there is such a thing as a tangible progressive elevation of the river bed.

During the height of the flood of 1903 the Mississippi River Commission viewed the river from St. Louis to the Gulf of Mexico. Anyone who could have seen, as they did, hundreds of miles of levee intact, the farmers behind them busy plowing and planting, the fruit trees in bloom, the stock fattening on the green herbage, would surely have been impressed with the efficacy, the necessity, of levees.

Add to this the knowledge that the levee system had served to fill with thrifty settlers the fertile basin where life without levees would be impossible, and it becomes incomprehensible how anyone can oppose the completion of the levee system, unless it be on the score of ignorance as to the facts in the case.

Contrast the peaceful condition of things where levee protection exists with the suffering and misery during a flood along the unleveed portions of the river, as revealed by a trip along the river during any flood, and no argument is needed to demonstrate the wisdom of a perfected levee system.

That occasional breaks should occur in levees, partially completed as to both height and section, is by no means surprising. They are to be expected, and they may occur under great stress on rare occasions even in a completed system. But the area flooded and the damage done on such occasions will be trivial, as compared to that of the general flooding of the entire basins under the "no levee" system.

The argument that the floods should be permitted to fill the basins in order that the sediment might build them up, so as to ultimately reach a height above overflow, has no substantial facts to justify it.

Mr. Ockerson. If it were practicable to deposit on the land all the sediment carried by the stream, it would still take a very great number of years to raise the general elevation of the 30 000 sq. miles of basins to any tangible extent. Then, too, the deposit could never reach the height of the rare, exceptional floods; and, if the doctrine is true that the bed of the river is rising, the relative height of bed, banks and flood would remain the same and overflows would always continue.

There can be no reasonable doubt as to the possibility of constructing an effective levee system. Far more elements of uncertainty are involved in many engineering problems that have been carried to successful completion.

The engineers of this progressive age will not falter in their conviction that the floods of even the mighty Mississippi can be effectually controlled, and it is not likely that a nation with such great resources as ours, which has undertaken to make the deserts blossom, will hesitate to contribute generously to a project which has for its object the conversion of the vast alluvial basins into fertile fields tilled by a prosperous people, happy and contented in homes of plenty.

Mr. Haupt. LEWIS M. HAUPT, M. Am. Soc. C. E. (by letter).—In this topic, the question is asked "Is the levee theory justified by experience" on the Mississippi River?

This query recurs with each successive high flood, and the river enters its solemn and devastating protest by breaching its ramparts and distributing its surplus where Nature designed it to be deposited. In this respect, the Mississippi Valley does not differ from any of the alluvial plains of the world, and it will be found more satisfactory to study the lessons of their experience rather than spend large sums in experimentation on works which, after all, may not accomplish their purpose. Some of these works of the ancients have been in existence for millenniums, and their magnitude and success have excited the admiration of all civilized nations.

Before referring to them, however, it may be well to state briefly the general operation of the physical law which governs the movement of a great river on its course to the sea.

Celestial and terrestrial gravitation are the upper and the nether millstones which grind the fertilizers stored in the mountain fastnesses, and feed them to the hydraulic conveyors to be transported to the alluvial plains for their reclamation and enrichment.

In the Divine economy, the rivers appear to be the agents for the extension of the habitable regions of the earth, by means of floods. In this process of hydraulic grading and filling, the heavier portions of the silt are deposited near the banks, so that all such rivers are found to run on a ridge and to drain away into lower swamp lands beyond. In the human economy, man occupies the batture along the river banks, and, to protect his property and life, attempts to hold

back the floods by dikes. When this system of defence becomes so general as to cut off the flood waters from the back lands they must cease to fill and must remain stagnant, while all the sediment must remain in the main trunk of the drainage system, and, as the slope and velocity grow less on approaching the mouth, a large portion of the load is lodged permanently in the bed of the stream. Mr. Haupt.

In a state of Nature, the river builds up its mean and low-water bed, and provides for the depositing of its surplus mud and water on the outlying flats bordering the stream. Wherever man has interrupted this process, without providing for a substitute by a supply of water and fertilizer, the garden spots of the earth have been converted into deserts, in which case there is no need for a navigable channel to carry away the products.

The vital importance of the irrigation of the bottom lands is well established by the history of Egypt, the arrogance of whose kings led to the destruction of the reservoirs and canals and the debasing of the country to a condition of servitude, as stated in the prophesies of Ezekiel.*

"Speak, and say, Thus saith the Lord God; Behold, I am against thee, Pharaoh king of Egypt, the great dragon that lieth in the midst of his rivers, which hath said, My river is mine own, and I have made it for myself. * * * Behold, I will bring a sword upon thee, and cut off man and beast out of thee. And the land of Egypt shall be desolate and waste. * * * Behold, I will give the land of Egypt unto Nebuchadrezzar king of Babylon; and he shall take her multitude, and take her spoil, and take her prey; and it shall be the wages for his army. * * * Because thou hast lifted up thyself in height * * * I have therefore delivered him into the hand of the mighty one of the heathen; * * * upon the mountains and in all the valleys his branches are fallen, and his boughs are broken by all the rivers of the land; * * * To the end that none of all the trees by the waters exalt themselves for their height, neither shoot up their top among the thick boughs, neither their trees stand up in their height, all that drink water; for they are all delivered unto death; * * * I covered the deep for him, and I restrained the floods thereof, and the great waters were stayed: and I caused Lebanon to mourn for him, and all the trees of the field fainted for him. * * * This is Pharaoh and all his multitude, saith the Lord God."

Thus, by the restraining of the floods and the withholding of the waters were the haughty nations destroyed by those heathen kings whose hydraulic works had made them powerful.

The source of Egyptian prowess is also beautifully set forth by the prophet when he says:

"The waters made him great, the deep set him up on high with her rivers running round about his plants, and sent out her little rivers unto all the trees of the field. Therefore his height was exalted above all the trees of the field, and his boughs were multiplied, and his branches became long because of the multitude of waters, when he shot

* 29th chapter.

Mr. Haupt. forth. * * * and under his shadow dwelt all great nations. Thus was he fair in his greatness, in the length of his branches: for his root was by great waters."

In this great country of ours we find the striking paradox of one of the executive departments straining every nerve to store and irrigate the soil, while another department is contending with a mighty river for its total exclusion, yet both having the same purpose in view, namely, that the earth may bring forth more abundantly.

The lessons of history teach that the total exclusion of the flood waters results in a devastation far greater and more disastrous than the temporary damages from the floods, and that in the non-irrigated portions of India and China human beings are dying from starvation, because of the confining of the waters. The question is not a local one, and should be considered carefully with reference to its far-reaching effects on posterity. The system in use on the Nile during its period of great prosperity was not the levee system, which excluded the river waters from the neighboring farms; but the basin or reservoir system, which caught and stored the excess waters of the floods, and, by regulating sluices, passed them from one pool to another along the banks of the stream, and finally returned them to the trough after their beneficent work was done, and without deterioration to the navigation of the river.

The importance of a full understanding of this experience will doubtless justify a few extracts from the records of the early systems used in the Orient in the days of the Pharaohs.

In a recent lecture, before the Khedivial Geographical Society, at Cairo (1903), Sir William Willcocks said:

"The advisability of Egypt undertaking these reservoir works without any loss of time has been well brought before me by a letter just received from Professor Sayce, in which he says: 'As you know, archæological facts have convinced me that * * * the body of water in the Nile is considerably less than it was only 2 000 years ago, when huge boats could be navigated at the period of low Nile; and the destruction of the great forests of Central Africa by the inroads of western civilization will further diminish it. Lake Chad and the dried-up lakes connected with it are ominous reminders of what can happen when forests are cleared away.'"

In describing the modern system of "perennial" irrigation now in use in Egypt, Sir William sounds a note of warning, to the effect that it can only survive during times of peace, and by constant care, while the ancient or reservoir system was as enduring as the pyramids, and survived neglect.

He says:

"Perennial irrigation is no hardy plant like basin irrigation, it needs perpetual and constant attention; it is typical of the structures of our days, the dams and weirs on the Nile, which need unremitting toil and observation to preserve them from destruction. The basin irrigation of the ancient Egyptians depended entirely on the flood

waters of the lateral tributaries, as the Atbara, the Blue Nile and the Sobat, which no engineering effort could turn out of the Nile Valley. The perennial irrigation of our day is chiefly dependent on the summer supplies of the great equatorial lakes and other reservoirs at the head of the drainage system. * * *

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"Under the old Pharaonic system of basin irrigation, the Nile flood was the Ministry of Agriculture, and the Irrigation Department sufficed to supply all the requirements of the country. Under the modern system of perennial irrigation the Irrigation Department does only half the work."

As a protection against disastrous inundations, he adds:

"Fifty years hence we shall find the country protected from high floods by escapes into the deserts. * * * Such an escape could be constructed for £3 000 000."

The Nile flood will have been maintained at a level sufficiently high to allow of the utilization of the water-power to its utmost limits, or 150 000 H.-P. for storing electricity and providing perennial irrigation by pumpage for other high tracts of 50 000 acres.

The whole process of the successful and safe treatment of the reclamation works of Egypt is stated briefly in a paper prepared for the Glasgow International Congress in October, 1902, in which Sir William said:

"If we cast our view back to the dawn of Egyptian history, we can picture the Nile Valley as consisting of arid plains, sand dunes and marshy jungles, with reclaimed enclosures on the highest lands. Every eight or ten years the valley was swept by a mighty inundation. We may well imagine with what awe the ancient Egyptians contemplated laying their hands on the great river and saying to it 'thus far and no further.' The seeds of future success lay in the resolve of King Menes' engineers to confine their attention to one bank of the river alone. It was the left bank of the river which history tells us was first reclaimed. A longitudinal dike was run parallel to the stream, and cross-dikes tied it to the Lybian hills. Into these basins or compartments the turbid waters of the flood were led by natural watercourses and artificial canals, and meantime the whole of the right bank and the trough of the river itself were allowed to be swept by the floods. * * *

"In all probability the first six dynasties contented themselves with developing the left bank of the Nile. As, however, the population increased, and with it the demand for new lands, it became necessary to reclaim the right bank as well. The task now was doubly difficult, as the river had to be confined to its own trough. This masterful feat was performed by the Great Pharaohs of the 12th dynasty. They were too well advised to content themselves with repeating on the right bank what Menes had done on the left. By suddenly confining the river they would have exposed the low-lying nomes of Memphis and Lower Egypt to disastrous inundations. To obviate this, they widened and deepened the natural channel which led to the Fayum depression in the Lybian hills, and converted it into a powerful escape to carry off the excess of waters of high floods; and so successful were they in their undertakings that the conversion of the Fayum depression into Lake Moeris was long considered by the ancient world as one

Mr. Haupt. of the greatest wonders. They let the flood into the depression when it was dangerously high and provided for its return to the river when the inundation had come to an end. By this means they insured the lake against being at a high level during a period of flood. The gigantic dikes of entry and exit were only cut in times of emergency, and were reconstructed again at an expense of labor which even Pharaoh considered excessive."

Thus the history of the Nile confirms the projects which have been thus far unsuccessfully urged for the reclamation and navigation of the great river which drains the most productive section of this Republic. It illustrates the need of lateral overflow for fertilization, of subsidiary reservoirs on the banks and tributaries to retain the excess of the floods from the headwaters, or to restrain those of the lower tributaries and of the enlargement of the mouths and outlets of the delta to lower the flood planes of the low country and deepen the channel for navigation, by removing the bars. May we not learn more from precedents than from experiments, and at much less cost? The dredging out of the obstructing bars in the Tyne between Newcastle and the sea has lowered the flood plane at different points from 3 to 9 ft.

Let us review, however, as briefly as may be, some of the statements relating to the Mississippi, to ascertain the facts as presented by the advocates or opponents of various plans of improvement.

The Mississippi River Commission was created by Act of Congress in the year 1879, when the South Pass was opened at its mouth. Its personnel has changed from time to time, but it has been composed of able men having the courage of their convictions, who have collated a large amount of valuable data as to the physics and hydraulics of the river. It has modified its methods, as the exigencies and experience acquired have justified, both locally and generally. It has tried regulation for low stages, revetments and spurs for holding caving banks, levees for floods and reclamation, and finally dredging, for navigation, and the results of this experience have been summed up in concise form in the Report of the Senate Committee, submitted after the severe flood of 1897. This Committee took a large amount of testimony and examined the works carefully, with a view to determine the following points:

1. To determine the causes of the disastrous floods, and how they may be prevented or diminished.

2. If the floods are due to deforestation, how it may be prevented, or whether reservoirs at the headwaters would be beneficial.

3. Whether such reservoirs could be used for irrigation of arid lands.

4. Whether the outlet system is practicable or expedient.

5. Whether the levee system, with jetties to protect the banks, should be continued.

6. What has been the effect of the jetties at the mouth upon the commerce and navigation of the river? Mr. Haupt.

7. Whether the Mississippi and the Missouri River Commissions should be continued.

8. What legislation is necessary to prevent the enormous destruction of property by floods, and what amount of money should be appropriated for the establishment of systematic improvements and safeguards.

The Committee concluded that the destruction of timber does not tend to cause floods, but rather to diminish than increase the rainfall. That the five large reservoirs on the Upper Mississippi repress, to some extent, the floods above Lake Pepin, and improve the low-water navigation down to that point. A high reservoir on the Missouri above Great Falls would be useful for irrigation, but not for navigation or floods. The Ohio has no adequate reservoir sites.

"The only place where a reservoir basin can be found, proximate and sufficiently large to afford a holding ground at all commensurate with any material or practical relief is the St. Francis Basin; but the cost of constructing and maintaining a system of reservoirs in this basin would be enormous and far greater than the cost of leveeing the entire river front of the basin. The scheme is regarded by nearly all engineers and other experts as wholly impracticable. In short, your committee can discover no just or adequate relief in reservoirs."

"Neither can it discover any material relief from the outlet system. It is not practicable to relieve the river by means of outlets except below the Red River. The St. Francis, Yazoo, White and Tensas Basins can get no relief from any practicable outlet system, and where this system exists and is feasible there is no disposition to extend it or to substitute it for levee enlargement."*

With reference to the levees, the Committee states that their history has been one of gradual reclamation. Anterior to levee construction these basins served as great natural reservoirs for the floods, which never reached the high level nor the increased rapidity obtained since the great extension of the levee system. Levees are the penning up of the floods of the river from these high-water basins, and the stream at its flood stages becomes higher, necessitating higher and stronger levees. The first levees in Louisiana were but 4 ft. in height, they are now 12 to 13 ft., and this height proved insufficient in the great flood of 1897, when the flood stage above New Orleans was from $1\frac{1}{3}$ to $3\frac{1}{2}$ ft. higher than that of any previous flood, notwithstanding that the flood level at Cairo was less than in 1882, 1883 and 1884. This was partly due to the increase and improvement of levees. The experience of 1897 indicates that a complete inclosure of all the river basins will require levees from 3 to 4 ft. higher in Louisiana.

The levees in the Yazoo Basin, originally only 4 ft. high, were increased to an average of from 13 to 14 ft., prior to 1897, which was more than 3 ft. above the high water of 1882, but it proved "utterly

* Humphrey's and Abbot's report of 1861, as to reservoirs and outlets.

Mr. Haupt. insufficient under the flood of 1897," which made it plain that the complete inclosure of all the basins would require an increase in the Yazoo levees of from 4 to 6 ft. The same is true of the White River Basin, which was overtopped by the flood of 1897 at many points, as it rose from 4 to 6 ft. above any previous flood.*

The upper and lower Tensas Basins were leveed since 1882 to a height of about 13 ft., but the water of 1897 was from 2½ to 3 ft. higher in front of these basins, and the levees were insufficient. The higher flood was largely due to increased levee construction. The completion of the levee system would require the levees in the Tensas Basin to be raised to the height of from 17½ to 18 ft.

Work on the St. Francis front began in 1893. Since that time about 127 miles have been constructed to an average height of 9 ft. The levees proved insufficient for the flood of 1897, and several serious crevasses occurred. They must be made at least 2 ft. higher. The flood of 1897 wrought great havoc. There were twenty-three breaks in the St. Francis front; six in the Yazoo; fourteen in the White; four in the Tensas, and a few below the Red which were unimportant. (It may be well to note here that these unimportant breaks, which were closed during the pendency of the flood, were below the outlet *via* Red River.)

The Committee concludes that the flood of 1897, in its effects and consequences, was greatly enlarged and aggravated by the extensive inclosure of basins and the extended and enlarged levee construction which has taken place since then. It refers to the early report of 1861, made when levees were in their embryonic stage, as authority for the statement that "no substantial relief from the floods could be obtained from reservoirs or outlets, and that levees properly constructed, would afford the necessary relief and protection." Subsequent reports sustained this contention, and, in view of the record and accumulated experience with this system of protection, it is somewhat disconcerting to find the Committee reaffirming the earlier opinions to the effect that "the river can only be protected and preserved from such floods by an ample and complete system of levees from Cairo to the head of the Passes." It adds, crevasses are liable to occur as long as the system is incomplete, and it was then (1897) estimated that it could be done at a cost of from $18 000 000 to $20 000 000 in from four to five years. That time has elapsed, and the flood of 1903 has added its testimony to the inefficiency of the protection works, and shows no substantial gain as to increase of depths or permanency of channel.

A few citations from residents and engineers on the Mississippi may serve to reveal the true status of the question.†

* To add 6 ft. to a 14-ft. levee doubles its volume and cost, increases its unit pressure, length of saturation, and hence its danger of caving.

† "Riparian Lands of the Mississippi River," by Tompkins.

A member of Congress from Mississippi says: Mr. Haupt.

"The levee system being very much stronger and more extensive than ever before, the flood elevation all along the river was greater than during any previous floods. This, of course, was to be expected."

On the other hand, an engineer of long experience stated:

"Having the St. Francis Basin closed cannot raise the high-water line one foot at Helena but will doubtless restrain it slightly, which reduction will continue as the shoals are scoured out by the restrained floods."

He does not explain how these shoals get out of the river's bed.

Still another authority states that:

"Since 1882, with the growth of the levee system and the gradual elimination of reservoirs, and contraction of the high-water sections, the flood plane had risen, each high water, for a given volume of discharge, giving greater gauge readings."

A comparison of readings showed that the flood of 1897, although 0.3 ft. lower at Cairo, was 5.6 ft. higher at Helena; 5.1 ft. higher at Greenville; 2.0 ft. higher at Natchez; 1.7 ft. higher at Red River (where there is an outlet); 4.7 ft. higher at Baton Rouge, etc., thus leaving no doubt in this instance of the increased height due to the additional contraction of the waterway and the lowering of the head relatively by the existence of an outlet.

The effects due to the later extensions may be seen by reference to the unofficial reports of the flood of March, 1903.

On the 20th of that month the gauge at Memphis, abreast of the St. Francis Basin, registered 40.1 ft., and seven days later a crevasse occurred at Hollybury, 20 miles north, which in one night lowered it to 39.4 ft., as compared with 37.7 ft. in 1897, the highest previous record.

At Greenville, Miss., the water was reported to be 4 ft. above any previous record, and rising at the rate of a half a foot per diem. A week later a "three-mile crevasse" was reported south of that place, said to be the worst ever experienced.

At New Orleans, on March 28th, it was reported to be 20.2 ft., or from 0.6 to 0.7 ft. higher than all former records, but, fortunately, the tension was relieved by a crevasse at Hymelia, about 40 miles above the city, which was not closed during the flood.

The record leaves no doubt that as the levees are extended and the flood waters withdrawn from overflow, the stage rises and the dangers resulting from crevasses still remain as a menace. The completion of the system is expected to establish a limit to the height of the embankments, but this expectation is based upon the assumption that all the sediment carried into the trunk by all its tributaries must be ejected at its mouth, as the natural deposit over the banks has been cut off. Even if this were a physical possibility, which it is not, for the reasons previously stated, the rapid extension of the delta

Mr. Haupt. by the enormous deposits would continue to retard the discharge and raise the flood plane, requiring constant accretions to the section all along the line to prevent overtopping. But this is not the only source of danger or expense. The erosive action of this great torrent at the bends, and especially at the contractions, incidental to the great variations in cross-section, is an ever-present source of danger, causing caving of the banks and their superimposed levees, which it is estimated goes on at the average rate of nine acres per annum for each mile between Cairo and the mouth of the Red River, and this risk increases with the height, because of the increased head, saturation and duration of the higher water. It is asserted by engineers of experience on the river that the bed is not rising, although they state that the contrary opinion is widely prevalent; but, when asked for a reason, those who believe it is "can give none except, perhaps, of a fantastic sort." It remains for those who deny it to account for the disposition of the large accretions fed to the river by its tributaries when the natural dump is cut off. This is attempted to be explained by the statement that the conditions indicate that "the alluvial agencies have nearly reached a state of equilibrium, and the further progress of the filling-up movement is exceedingly slow." This recognizes, but minimizes, the action as negligible.

The revetment of caving banks has been tried extensively, but is now almost abandoned. The testimony is to the effect that:

"The revetment idea at first inspired some hope, but it was soon seen that its cost and want of permanency would confine it to a few points. It was therefore with much satisfaction that we saw the dredging and portable dike idea introduced."

Another engineer writes:

"The absolute failure of mattress work to protect abrading banks has been very thoroughly and positively demonstrated."

Another states that:

"The use of contraction works has been abandoned to a great extent, and the general improvement of the river by bank protection, revetments, spurs, etc., has been postponed until some less expensive structures are designed or discovered. * * * The low-water channels are being maintained by dredging during the low-water season. * * * The St. Francis and Yazoo are of little consequence, except in that their basins act as relief areas or reservoirs during high stages of the river."

Such, then, are but a few of the many statements and opinions concerning the experience and results secured on this great river, from which it would appear that the end is not yet, and that important remedial measures have been brushed aside without the consideration which their possibilities demand.

Outlets.

It is an axiom that if the outflow from a vessel be made equal to or greater than the inflow there can be no overflow, and yet the applica-

tion of this simple expedient is condemned as being injurious, impracticable, or too expensive, and the eminent authorities of the earlier investigations are cited as being opposed to this method of relief. So important is it that a brief consideration appears to be warranted by reference to the original sources. Mr. Haupt.

The injurious effect of outlets is generally stated to arise from:

"The escape of water from the channel, which, under any circumstances, is accompanied by a reduction of velocity below the point of escape, and which thus creates deposits in the channel and dams the discharge."

Another says:

"Outlets will induce a shallowing of the river and a raising of the bed, and consequently of the water line. In short, the only one of the remedies above mentioned that is satisfactory to those concerned or that has had any extensive application, is the method of artificial embankments or levees."

This statement, that the outlet system has had no extensive application, would indicate that it is purely theoretical, although the natural outlets amply demonstrate the claims of their supporters, as will presently appear. The Nita crevasse of 1890, 60 miles above New Orleans, is cited as an evidence that the outlet system is useless as a measure of relief. This is merely a question of interpretation. What were the facts?

"This crevasse was 3 000 ft. wide and 15 ft. deep. It discharged 400 000 cu. ft. per second, or 30% of the flow, as measured just above the crevasse. The depression of the flood surface immediately below was 1½ ft. At New Orleans it was 1 ft. At Plaquemine, 50 miles above, it had no effect at all."

From this instance it was concluded that:

"Outlets must disappoint the expectations of their advocates as was noted by the able pioneers in this subject, Generals Humphreys and Abbot, who, lacking actual measurements, supported the proposition by a very ingenious method of indirect proof, which showed in part, but not completely, the futility of outlets as a means of flood relief."

On the contrary, the Nita data prove that the outlet lowered the surface of the river for at least 100 miles, by from 1 to 1½ ft., and saved the city of New Orleans. That it did not lower it 50 miles above, is accounted for by the fact that the supply from the higher reaches was such as to maintain the stage which the slope and sinuosities of the bed for the 50 miles below prevented it from voiding. Had not the breach occurred, the stage at New Orleans would have been at least 1 ft. higher. It was flush with the crest when the crevasse occurred. It was therefore a positive measure of relief to the entire river below the break, and for some distance above, and its injurious effects on the stream, if any, remain to be discovered. So, with the many other large crevasses which have occurred in the stretch between the Red River outlet and the mouth, where, in consequence of the many outlets, the

Mr. Haupt. stage is more constant than in any other section of the river below St. Louis, and the navigation is most satisfactory.

A distinguished member of the Mississippi River Commission* thus describes this outlet section:

"In this portion of the river the channel is narrow, averaging about half a mile in width, and the depth sometimes exceeds 200 ft. Bank erosion is slight as compared with the reach above, sand bars, as obstructions to navigation, are almost unknown, and neither contraction works nor dredging are required. Here Nature has constructed an ideal channel, with depths at all times sufficient for the largest sea-going craft. For nearly the entire length (310 miles) the water is confined to a single channel, down to the head of the passes, there being but two islands in the entire reach. As the upper limit of the reach at low water is less than 2 ft. above mean Gulf level, it often happens that the tidal effect is noticeable throughout its entire length. There are several outlets through which the waters of the river can flow to the Gulf of Mexico. Some have been closed by levees, but others are still open. At the head of this reach is the Atchafalaya, which is the first practicable outlet to the sea. * * * The extreme oscillation in stage recorded up to the present time at New Orleans is 20.7 ft."

Such, then, are the characteristics of this outlet section of the river, with its minimum of fluctuations, deepest water, fewest bars, least erosion, and best channel, all of which may be ascribed to that one feature which all the sections above lack, namely outlets; and yet it is claimed that the outlet propaganda is merely a fanciful theory, not based on experience. What would become of the country if there were no outlets? This is an extreme case, it is true, but every obstacle at the mouth of a river contributes in some measure to dam it up and raise the level by reduced slope and velocity.

With reference to the "claim that actual measurements confirm the opinion that outlets must occasion deposits in the channel," Humphreys and Abbot say that after a careful investigation of the sections at certain crevasses, these claims "fall to the ground." They also add that an extended series of measurements was made with especial reference to testing the assumptions upon which are based the conclusions that outlets will raise the mean level of the bed of the Mississippi, and "they have demonstrated both to be erroneous."

Speaking of outlets, they say emphatically:

"The conclusion is then inevitable, that, so far as the river itself is concerned, they are of great utility. Few practical problems admit of so positive a solution."

They then proceed to consider the various channels whereby the flood waters might be conveyed to the Gulf, and appear to have been deterred from recommending them because of what appeared to them, at that time, to be the great cost of such relief measures, and the local injury to the rear of some low-lying plantations.

*J. A. Ockerson, M. Am. Soc. C. E.

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It is stated that the distance between the river and Lake Pontchartrain is only six miles, and the fall is 19.6 ft. at high water (1851).

"There can be no doubt that by making two levees from the river to the lake a high-water outlet of any dimensions can be made. Such an outlet, they say, would be of utility in reducing the height of the floods for many miles above and below, but its construction would be followed by consequences disastrous to Louisiana."

What these disastrous consequences were, which outweighed the benefits of reduced floods in 1861, are thus set forth: (1) the works must be difficult and costly; (2) the navigation of the lake will be rapidly destroyed; (3) there is danger that the outlet will become a main branch of the river; and (4) the navigation of the present mouths be thus seriously impaired.

With a new and shorter outlet to the sea, when the ruling depths by the delta mouths were wholly inadequate, and with the navigation of the lake improved by the better channel to be created, it is difficult to understand how such works would have proved disastrous to Louisiana.

In considering the length of time required to destroy the navigation of the lake, it was assumed that the river discharged a volume of sediment equal to 1 sq. mile, 21 ft. deep, each year; and at this rate it would require 375 years to fill the lake, if it were all deposited in it, which could not be expected. But, even then, it does not appear that the filling up of a non-productive lake and the reclamation of 600 sq. miles of the most fertile land on the globe would be such a serious disaster to the State, while the value of that land would doubtless pay many times over for the cost of the works, so that the outlet would accomplish precisely what the levees are designed to do, namely, reclaim more land than it would destroy. The lowering of the flood plane throughout this section would also add largely to the available productive territory by a very simple and expeditious engineering work, which has been urged upon the attention of the Government for some years past, but apparently to no purpose.

After a careful review of this classic report, the writer is unable to find any other or more weighty reasons assigned by its writers for the conclusion which they reached, that "outlets are not advisable." It would seem to be unfortunate for the welfare of the country as a whole, and for Louisiana in particular, that this view should have become so deeply grounded. The river crevasses and the outlets of to-day tell a different story, according to some interpreters. As outlets are best for the river, and it is practicable to relieve it, not only at Lake Pontchartrain and Lake Borgne, but at other points, at a reasonable cost, and to reclaim more arable land by so doing, they would seem to be fully justified and worthy of being inaugurated.

To avoid any possible misconception, the writer desires to state that he does not condemn levees as an auxiliary device to assist in con-

Mr. Haupt. trolling the flood movements, and that by outlets, he does not mean the cutting of great natural breaches in the dikes, but suitably arranged spillways with sills at proper elevations above ordinary stages and surmounted by movable dams, shutters or gates, for the regulation of the discharge. As far as the practicability of these devices is concerned, there can be no question, as the Government has made an excellent demonstration of their efficiency on the Kanawha and Upper Ohio Rivers and elsewhere.

Reservoirs.

Still another source of relief remains to be noted briefly.

At the Convention of this Society held at Old Point Comfort, in 1892, the writer submitted a few suggestions in these words:*

"It would seem practicable to provide a sufficient number of large lateral subsiding basins or lakes by enclosing extensive areas at intervals where the topography admitted of economical construction, into which the flood waters could escape, and in which, the velocity being reduced, a large part of the silt would be precipitated, while, after the passage of the crest of the flood-wave, the clearer waters from the reservoirs would return to the river and become useful for navigation. In short, instead of serving the sole purpose of maintaining the water supply for low stages, * * * they would also reduce the rate of raising the bed by providing lateral dumping grounds outside of the bed of the stream, and would also reduce the flood plane and dangers from inundation. There are numerous places on the river where, by making return dikes extending back to the bluffs, many square miles of land, now of little value, might be utilized for such safety valves for the river, with substantial benefit and at a comparatively small cost.

* * * * *

"The systematic improvement of the river must treat the problem as a whole, and provide at high stages for the rapid emptying of its basin at the outlet, the retardation of its filling by its tributaries, provision for deposition of its load and temporary escape of its excess of water along its course; while for the low-water stages for navigation the stream must be canalized so far as practicable to retain a nearly uniform velocity."

In the discussion of these suggestions, which followed, it was stated that:

"It is not established that general relief is found by using these basins to receive and hold back for a time the water overflowing into them from great floods."

As no such basins have ever been created on the Mississippi, there is no local experience upon which to base this objection, for the natural overflow and run-off are not the conditions contemplated, but a series of reservoirs for which the Senate Committee said this reach was well adapted, the only objection it raised was to the cost, which it thought would be greater than that of leveeing the entire front of the basin. But that is not the proper basis of comparison as to cost,

* *Transactions*, Am. Soc. C. E., Vol. XXVII. p. 302.

since the closure of the basin not only involves the cost of the levees along its front, but the elevation and strengthening of nearly the entire line from Cairo to the sea, compared with which the cost of the reservoir and regulating works would be a small item. In addition thereto, there would result a definite control of floods, a slack-water navigation for more than 300 miles of river, a series of reservoirs for storage and irrigation canals, and the reclamation of much arable land along the banks, all the way down the river. These benefits are sufficient to warrant the construction of the system which has been so fully and carefully described* by James A. Seddon, M. Am. Soc. C. E. In this paper it is stated that "a 20-ft. channel, navigable at all seasons, is shown to be feasible, by the group of professional men best qualified to judge." Mr. Haupt.

The painstaking researches given to this all-absorbing question by one whose life has been spent in these studies, entitle them to great weight, and they reveal the practicability of so regulating the river floods, and at the same time of providing a sufficient channel, as to commend them to the earnest attention of the Government.

It is not reassuring to be told that when the levees are complete the lands behind them will be safe from inundations, for it is only necessary to look to recent experiences in other countries which have taken refuge in long-completed levees. In China, for example, it has been officially reported that the Yangtse Kiang had broken out recently above Nanking, the water reaching the highest stage in fifty years. The devastation was widespread. Villages, farms, crops and live-stock were swept away, and famine stared the people in the face. The loss of life was very great, thousands being drowned, and the natives were living in the trees. Riots and robberies prevailed as a result of suffering from famine. This catastrophe occurred in October, 1901.

In another instance, it was reported that 3 000 000 persons were drowned by the bursting of the levees along the Yellow River, which has been appropriately designated as "China's Sorrow," because of the great destruction wrought by its floods.

With reference to the present experience in Egypt it is stated that:

"The necessity of constructing levees to exclude the Nile water from the cotton-growing fields has rendered the inundations destructive, and the speculation seems on the whole to have injured the welfare of Egypt."

But there is another feature of the levee system to which attention should be directed before dismissing the subject, and that is the great irregularity in cross-section which it necessarily introduces in consequence of the bends of the stream and the character of the supporting ground, thus violating one of the most important requisites for the permanent improvement of a stream. A mere glance at the maps

* Paper read before the Western Society of Engineers, June 20th, 1900, and reprinted by the Illinois River Valley Association.

Mr. Haupt. will serve to impress this feature of the levees. For example, at Mile 430, below Cairo, the distance across the river between the jetties is about 1 mile; thirty miles higher up it is about 15 miles. Ten miles below it is 5 miles; in 20 miles more it widens to 8 miles, and 5 miles lower contracts to 1 mile. This great irregularity of width necessitates corresponding fluctuations in depths at high water, with high velocities at the gorges and deep erosion resulting in higher shoals and bars in the wide reaches, thus building up obstacles to navigation, as may be illustrated by the detention of the monitor *Arkansas* at St. Genevieve, Mo., during the period of the year when the river is supposed to be navigable for vessels of that limited draft.

In many places the building of a few miles would have saved from five to ten times as many and have given a far better alignment.

Conclusion.

To bring this many-sided question to a conclusion, it may be said that outlets and regulating reservoirs or basins have not had the consideration which their many advantages demand for them, but have been dismissed on theoretical grounds, while the ancient experiences demonstrate them to be the most important factors in contributing to the success of great river regulation, with the result of ultimately reclaiming and protecting more land and rendering it more productive than a system which looks to the almost total exclusion of that element so necessary to agriculture, water. The levees undoubtedly increase in height with the extension of the system, they overload the banks, do not prevent caving, do not regulate the stream, increase the fluctuations between high and low stages, instead of securing a more nearly normal discharge, and are in themselves very expensive to create and maintain, being subject to the direct attack of the flood forces.

The national prosperity is largely dependent upon the maintenance of the great central basin as a granary for domestic and foreign supplies, and hence the question should be carefully and fearlessly considered solely on its merits. It is believed that this can be done to great advantage by the members of this Society, and that the topic is timely and deserving of the fullest consideration.

* * * * * *

The foregoing discussion was prepared prior to the presentation of the discussions at the Convention, and the writer, having read the latter since that time, thinks it necessary to add a few supplementary deductions.

From the discussions by several members of the Mississippi River Commission, it appears that all are agreed as to the ends to be secured, namely, the reclamation of the fertile lands of the Mississippi, but that there are honest differences of opinion as to means, as well as of interpretation of data, which remain to be reconciled.

Mr. Haupt.

The Commission's present plan appears to lay stress upon levees as the sole means of reclamation, with incidental channel improvement, supplemented by dredging, and it appears to deny the statements, so generally made and believed, that the effect of the levees would be to cause the bed of the stream to rise; while others, and among them the writer, having full faith in the levees as a partial remedial measure, would supplement them by reservoirs, outlets and other devices, and prefer to take the record of thousands of years as to elevation of bed, to that furnished by surveys covering only a period of some thirteen or fourteen years. However, if Tables Nos. 1 and 2 and the diagram, Fig. 1, prove anything, it would seem that there has been a loss in the low-water mean depth, or an elevation of bed, of about 6%, and in the medium depth of from 6 to 8%, while the bank-full stage of Table No. 2 shows a loss in mean depth of 8.9%, notwithstanding the increase in width in each case. They also show losses of about 3.7% in area for both stretches, at low water; and in 1894 the upper section gained 2.7% in area at medium stage, while the lower section of the river, from Vicksburg south, lost 0.8% at medium stage.

The composite diagram also indicates clearly an elevation of the bottom averaging about 4 ft. (the scale is too small for any accuracy) at low water and an enlargement between low and extreme high water, which enlargement in width does not improve navigation, but represents the amount of detritus fed to the stream by the caving banks, a portion of which is accounted for in the fill at the bottom of the cross-section. The question at once arises as to the disposition of this material eroded from the caving banks and (as determined by planimeter from this small drawing) amounting to 8.6% of the mean cross-section covering 200 miles of river. Since there are supposed to be no outlets whereby it may escape from the stream, there would seem to be no alternative but to expect it to be deposited in its bed or be carried bodily to the Gulf; but it has never been claimed that the deposit at the mouth is equal to the sediment fed to the bed by tributaries and caving banks. Hence the conclusion is inevitable that the bed as a whole must rise. This elevation must become more rapid as the area of deposit is confined by levees. The entire alluvial deposit of the basin is the recorded answer of Nature as to bed elevation, and it is illustrated further by the salient spits of land which jet out into the Gulf to support its bed and elevate the waters of the stream above the general level of the Gulf.

The general facts stated in the tables, resulting from the carefully conducted surveys made under the direct supervision of one of the most experienced and competent civil engineers in that service, reveal shoaling of the mean depths at low-water and medium stages, reduction of low-water areas, increase of width and elevation of flood surface

Mr. Haupt. with large increase of bank erosion between high and low water; it would therefore seem to leave no doubt as to the contention that the bed is rising and the flood-plane with it. The latter is due more especially to contraction between levees than to bed elevation.

Table No. 4 also confirms, so far as such data can, the general experience that each successive high flood, of approximately equivalent volume, has overtopped its predecessor by some feet. In the flood of 1903, the gauge at Cairo was 1.57 ft. lower than the highest previous record, while that at Greenville, Miss., was 2.35 ft. higher than any former record, making a difference (other things being equal) of 3.92 ft. in height, due to levee extension. The same table shows that this flood of 1903, which was not a maximum at Cairo, overtopped the highest previous flood record all the way from Cottonwood Point to the Red River, with but two slight exceptions, while in the outlet section, below Red River, the surface generally was lower than the highest previous records. The profile of this flood, which has not yet been published, will show some very suggestive fluctuations of slope and discharge due to variations of alignment and width between levees.

Already, the menace in the vicinity of Memphis, caused by the partial closure of the St. Francis front, is such as to call for vigorous protests against its extension, since no provision has been made for relief, and it is admitted that:

"A crevasse in the levee of the future will be a more serious disaster than in one of the present time, in proportion to its greater depth and discharge, and the greater improvements which have developed under its protection."

Yet this menace is avoidable, and should be provided for in the scheme of improvement.

The standard levees have been revised frequently as to elevation and section, but, unfortunately, not as to alignment, where the greatest benefits are possible. But little attention appears to have been paid, in these discussions, to the serious irregularities in width between levees, causing pools and chutes, with great irregularity of discharge and slope, bar building and bank caving.

In 1897 it was estimated that the levee system could be completed at a cost of $20 000 000 in from four to five years, yet in the present discussion it is stated that at this date (1903) only 60% of the yardage now considered necessary for the safety of the plantations below their banks is in place, and that the experience of this year "makes advisable a revision of the provisional standard in the vicinity of some of the gauge stations."

Conclusions derived from average gauge readings at a few fixed points should have but little weight, since the shifting of the bars up or down a stream with reference to the location of the gauges, as well as the variation of width between banks, will affect their readings

materially. The increase in width alone, as shown in Tables Nos. 1 and 2, would, in itself, account for a relatively lower reading of the gauges, thus vitiating any deductions as to bed elevation, unless the corrections were applied, which does not appear to have been done. Mr. Haupt.

The reference to reduction of sectional area below crevasses, and their enlargement after closure as being an invariable experience, appears to be disproved by the records of sections made and tabulated by Humphreys and Abbot,* as well as by other competent authorities, for the special purpose of ascertaining the effects of such outlets.

The general physical characteristics of the stream between the Ohio and the Red River are thus briefly described by a distinguished member of the Commission.

"The bed of the stream is through deposits which it has built up and torn down repeatedly. * * * The caving in the middle third of this portion of the river reaches enormous proportions. A large percentage of the alluvial banks throughout the reach yields readily to the eroding power of the current, and this erosion amounts to an average of about 9 acres per annum for each mile of river. In places the river becomes excessively wide by encroaching on first one bank and then another; * * * again, it becomes exceedingly crooked by the continued erosion of the concave bank.

"The width of the river reaches a maximum in this reach, the high-water banks being sometimes two miles apart. The banks are 30 to 45 ft. in height above low water. Overflows are frequent, except where floods are restrained by levees. The sandbars are very large in extent, and wooded islands and towheads are numerous.

"The extreme range in stage from low to high water is about 53 ft., and the discharge varies from 65 000 cu. ft. per second at low water to 2 000 000 cu. ft. per second at high water (1 : 30).

"The destructive floods enter the alluvial basin at the upper end of this reach and sweep its entire length, gathering strength as they go, and often remain at an overflow stage for a period of nearly three months.

"The elevation of the upper end of the reach at low water is about 270 ft., and at the lower end the elevation is about 2 ft. above sea."†

From the foregoing extract it appears that this reach is characterized by great variation in width, height and volume of discharge, "enormous" caving, long periods of saturation of levees, insufficient depths on crossings, limited to about 5 ft., and frequent overflows and crevasses.

As the levee system is extended, an augmented volume of water is confined to the contracted area, thus increasing the variations of stage and discharge between high and low water and building up the crossing bars. Moreover, the general alignment of the levees as built is such as to cause still greater fluctuations of flow because of the variation in width, ranging from about 2 to over 20 miles, and creating

* See Chapter VI, Hydraulics of the Mississippi River; also Ellet on the Ohio and Mississippi Rivers.

† "Riparian Lands of the Mississippi River," F. H. Tompkins, New Orleans, 1901.

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a succession of lakes and gorges. The angular trace also opposes greater resistance to the discharge, by reason of the salients and re-entrants, which also add to the length and cost of the works, and increase the caving. In numerous places the construction of a few miles would save from two to three times the length and give a much better flow. These features are illustrated in the sketch of the Third District, Fig. 4.

Evolution of Levees.

The levee is primarily a barrier, erected to defend the plantations from the encroachments of floods. As such, its origin was local, confined to the lower elevations along the river and made to conform to the areas to be protected. These works were built by the earlier occupants of the rich farms, at their own cost, subsequently aided by the Parishes, then by Districts, States and finally by the General Government. The disconnected broken lines were enlarged and connected as the exigencies arose for the continued exclusion of the river from its natural outlet and dumping grounds, until they have assumed magnificent proportions, and yet they are not able to cope with the constantly increasing height of the floods. But the most unfortunate feature of this mode of development has been the absence of any general and systematic alignment for the regulation of the discharge at any stage of the river. The trace of the levees is characterized by a series of broken, angular segments resembling a line of military entrenchments so designed as to enable the adjacent enceinte to be enfiladed. Still more objectionable, however, is the great inequality in width between the lines of levees on opposite banks, or between one line of artificial levees and the natural bluffs, which range from about two to more than twenty miles, thus converting the bed into a series of pools or large lakes and chutes. These gorges, being unable to void the floods as rapidly as they enter from above, cause the lakes to fill and overflow, and also produce great irregularities in slope, thus cutting out the bottom at the gorges and filling up the lakes, which at low stages become more difficult of navigation, requiring the use of large hydraulic dredges to reopen the channels, which do not long remain open.

It would apparently afford great relief and a better navigation if the location of the levees were revised and the gorges opened by setting the levees back, which could be done in many instances at a cost which would be fully justified, in the reduction of the total length and in the benefits to both the channel and the farms.

It is suggestive that the cane growers of Louisiana are now advocating the introduction of a system of irrigation to increase the fertility of the lands from which the waters have been excluded by the levees. This must be followed logically by a system of drain-

Mr. Haupt.

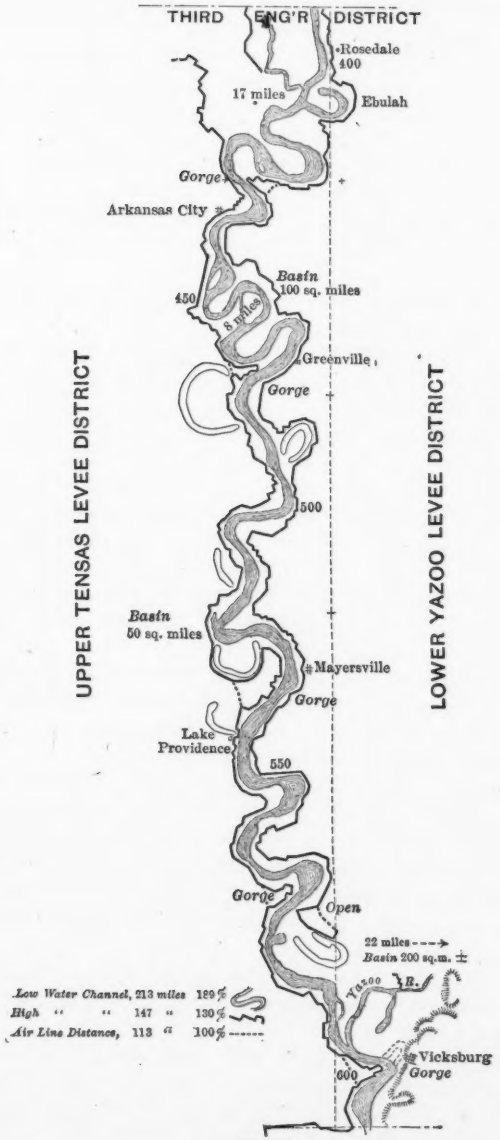


FIG. 4.

Mr. Haupt.

age and pumpage in places to restore the water to the river, running on the higher level. Fig. 4 will show the defects in the levee trace, as it exists to-day.

Experiments to Determine the Influence of Forms of Channels on their Discharge Capacity, as Applicable to Large Rivers.

Apparatus.—These experiments are submitted merely in the nature of suggestions, since the apparatus is necessarily so crude as to eliminate all refinements looking to very accurate results, and, even if they were possible, the conditions available would not resemble those in Nature.

As a type, a section of the Mississippi River was taken, covering the Third Engineering District, extending from the White to the Yazoo Rivers, the length being 213 miles by the river or 113 in an air line. Four tubes were taken to represent: (1) the actual length of the stream, following its convolutions at low water; (2) the same developed as a straight line; (3) the river at high water along the axis of the levees; and (4) the same developed.

The two low-water tubes were each 36 ins. long, and had a diameter of 3 mm. The high-water tubes were 23 ins. long, and had a diameter of 11 mm., which gave the straight tubes a relative capacity of 1:13.77. This was checked by filling a given vessel by siphoning through the tubes, under a constant head, which gave the relative times as observed to the nearest second, from a mean of several tests, as 14 : 1.

Experiments.—1. It was found that the receiver was filled by the large tube in 282 seconds, which, being divided by the relative capacity, 13.77, gives 20.44 seconds for the time required to fill the vessel by means of the smaller straight tube. The actual time, as recorded by a watch beating seconds, was 20 seconds, a close confirmation.

2. The low-water straight and bent tubes were then compared in a similar manner by passing a current through them and filling the receiver. It was found that while the time required by the straight tube was 282 seconds that by the bent tube was 1665 seconds, or, in other words, the distortions and bends of the path retarded the flow 5.9 fold.

3. While the large straight tube required 20 seconds to fill the receiver, the corresponding bent tube took 45 seconds, or two and a quarter times as long.

4. The large tubes were then filled and allowed to empty themselves by gravity. The straight one discharged itself in less than one second, while the expanded one required 9 seconds, due to variations of cross-section and interferences caused thereby.

Deductions.—From these experiments it appears that the capacity

of discharge of the convoluted, low-water conduit is but 17% of its rectified length, and that of the distended high-water channel is but 44% of its developed length, thus illustrating clearly the importance of channel rectification to facilitate the rapid discharge of floods. Mr. Haupt.

In a state of nature the river seems to be almost endowed with reason, in its nice adjustment to the demands made upon it, by shortening its length, increasing its slope, opening its mouths, and, if the flood comes on too rapidly, overtopping its banks and depositing its load in the bayous; or, at low stages, falling back into its serpentine bed, with increased length, retarded discharge and a better navigation.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

IMPERVIOUS CONCRETE.

An Informal Discussion at the Annual Convention, June 11th, 1903.*

SUBJECT FOR DISCUSSION:

"Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

By Messrs. R. W. LESLEY, J. JAMES R. CROES, J. W. SCHAUB, B. R. GREEN, OSCAR LOWINSON, EDWARD CUNNINGHAM and W. K. HATT.

Mr. Lesley.

R. W. LESLEY, Assoc. Am. Soc. C. E.—It is somewhat difficult to attack this subject, as the outlines of the field to be covered have not been very thoroughly defined.

Of course it is known that there is a great difference between the porosity and permeability of mortar, though in a great many minds these two subjects are considered to be the same. It is known that, as an engineering question, the permeability of mortar is a serious one, and the porosity of mortar is only interesting from a scientific standpoint.

On the question of mortars and the subject of permeability, the most learned writer is M. R. Feret, Chief of the Boulogne Laboratory of the *Ponts et Chaussées*, a well-known expert of the French Government. In his work on this subject,† which has not been translated, Mr. Feret

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV, p. 71.)

Communications on this subject received prior to September 25th, 1903, will be published subsequently.

† "Sur la Capacité des Mortiers Hydrauliques," published in the *Annales des Ponts et Chaussées*, July, 1892.

gives the results of a series of experiments begun by him in 1887, and pursued without interruption for a period of nearly five years. He gives the results of his experiments, embracing the most complicated tables and figures, covering in all some two hundred pages of press matter, and arrives at a number of conclusions which, in general, may be summed up as follows: Mr. Lesley.

1. The strength of mortars made on ordinary public works increases in proportion to the amount of lime or cement therein.
2. The strength increases generally at the beginning of the hardening in proportion to the size of the sand elements.
3. Mortars made with a mixture of sand containing large and small particles, present practically the same advantages as those where sands of large particles are used exclusively, and should be preferred to the latter.
4. The porosity of cement mortars varies very greatly. It diminishes as the proportion of cement increases. It is much greater when the sand is finer.
5. The permeability of mortars diminishes as the proportion of cement is increased; but, reversing the conditions applying to porosity, permeability increases according to the size of the sand grains. Mortars made with sand composed of different sized particles which themselves have little porosity, also very slight permeability.

The permeability of mortars submitted to a continuous filtration of fresh water or sea-water diminishes rapidly with time.

It is recommended to mix mortars to a good consistency by adding too large rather than too small a quantity of water.

Coming more definitely to the question of the sub-heads of permeability and porosity, he states, under the head of porosity, the following as the conclusion of his experiments:

"That all mortars are porous when submerged in water, and the absorbed water will conform quite nearly to the total volume of the calculated voids; that, however, there is a very great distinction between the permeability of mortars, that is, the property they have of permitting percolation more or less by water, and their porosity, that is to say, the quantity of water they will absorb when immersed, the latter of which, as already stated, is about equal to the total volume of the voids. In general, the most porous mortars are the least permeable, and the reverse applies to permeable mortars.

"The experiments showed that with coarse sand, the porosity diminishes, and it increases as the sand is fine."

To the question of permeability, Mr. Feret devotes many pages of his book, and has many experiments of a most interesting character. He finds that:

"Permeability is quite a different subject from porosity, and the effect of the passage of water may be said to free small particles of

Mr. Lesley. the lime or cement and bring them to the surface where they produce efflorescence or fine stalactites, according to the freshness of the mortar. These efflorescences tend to solidify the mortar and form an exterior coating. Tables are given to illustrate by experiment the effect of this water passing through the permeable mass, which demonstrates that when water is forced through a mass of mortar, stonework or concrete, or is allowed to go through, the fact that large amounts do go through at once does not indicate any lack of value in the mortar, because the first hour may show a considerable quantity of water going through, carrying lime particles which close the pores, and as the process is kept up, each hour shows a diminished volume of percolation."

"On page 97 of his book, in reference to the valuation of the permeability of the same mortar, there is a table showing the lessening of permeability, after a series of experiments beginning at one hour and covering a week, at the end of which time there was practically no water coming through. This was due to the fact that the pores were obstructed by the carbonates of lime which result from the attack of the cement by the lime-carrying water passing through it, and its subsequent exposure to the atmosphere.

As a general rule, it is observed that this lessening of the permeability of the mortar is just so much more rapid as the filtration through the mass is more abundant. In reference to this it would appear that where, after a long drying, mortar is subjected to water and there is a great quantity pouring through immediately, this is the best indication that the mortar ultimately will be absolutely impermeable to water.

On page 99, of Feret's book, referring to this subject, a quotation is made, from a paper* by Durand-Claye, which confirms these experiments and lays down the principle that, for each class of mortar and sand, there is a definite dose of water which corresponds to the maximum of compactness and the minimum of the permeability of the mortar.

In another series of tables, on page 100, with various proportions of water, it is shown that conditions govern largely the question of permeability, and also confirms the theory that the ratio of the permeability increases as the quantity of water increases. The permeability also depends upon the proportion of water, as stated above; and on page 101, there is a table showing that, at the end of a reasonable period, mortars made of varying proportions of water show about the same filtration, though at the beginning of the experiment there was a material difference in the quantity of water that percolated through them.

In another full series of tables, giving results with various sands, it is demonstrated clearly that the permeability is rapidly increased when the larger sizes of sand are used, while, on the other hand, decomposition is more active with mortars made with fine sand; and, in

* *Annales des Ponts et Chaussées*, Series 6, Vol. 15, p. 816, May, 1888.

summing up the subject of permeability, Mr. Feret comes to the following conclusions: Mr. Lesley.

"That in all mortars of granulometric composition, the most permeable are those which contain the least quantity of cement.

"Of all mortars of the same richness, but of varying granulometric composition, those which contain very few fine grains are much more permeable. They are the more so where, with equal proportions of the fine grains, the coarse grains predominate more in relation to the grains of medium size.

"The minimum permeability is found in mortars where the proportion of medium size grains is small, and the coarse and fine grains are about equal to each other."

In a very interesting paper by Messrs. G. W. Hyde and W. J. Smith,* a series of experiments to determine the permeability of cements and cement mortars was made, and these experiments were with both Portland and natural cements, neat and with varying proportions of water. They demonstrated very clearly that neat cements under pressures of 75, 100 and 200 lbs. per square inch, made in short 6-in. cylinders, 3 ins. in diameter, showed practically no permeability to water in 28 days, and only in the case of three of the samples in 7 days. With sand, however, the permeability increased as the percentages of sand were increased, the mixtures of 1:1 giving much better results than the 2:1 samples.

The conclusions which the writers drew from their experiments were:

"The results show that all cements are not permeable to water, at least for thicknesses of not less than 3 ins., while the mortars are all permeable; the amount increases with the pressure and decreases with age of specimen, but not in a direct ratio."

Comparisons are made by these writers between the permeability of cement and brick; and, referring to results on the Vanne Aqueduct, in France, they show that a conduit of béton-aggloméré, composed of sand and cement, showed practically complete impermeability.

Considerable attention was given to this subject by the Italian engineers in charge of the harbor works at Genoa, Italy, and many experiments were made to determine the porosity and permeability of mortars. Their conclusions were that:

"The porosity of mortars depends upon the existence of voids of three kinds: first, those existing between the grains of sand or pozzuolana and not completely filled by the cement or lime; second, those due to the air which adheres to the surfaces of the grains; and third, those left by the evaporation of the water used in the mixing."

These three classes of voids were thoroughly investigated and discussed. The conclusions arrived at were: That cement mortars are less porous than those made of hydraulic lime and sand or of ordinary lime and pozzuolana; that cement mortars made with coarse sand are less

* *Journal* of the Franklin Institute, Philadelphia, September, 1889.

Mr. Lesley. porous than those made with fine sand; that neat cement mortars are more porous than those made with sand; and that the proportions between the voids and the apparent volume of the mortar may vary from 12 to 46 per cent.

Paradoxical as it may seem, comfirming Feret's experience, however, the experiments showed that the permeability of mortars, so far from being a consequence of their porosity, is in fact almost inversely proportional to it. The exhaustive experiments made in this connection showed: That with the same proportions of cement, mortars made with fine sand are less permeable than those made with coarse sand; that, with the same quality of sand, permeability decreases as the proportion of cement increases; that mortar made with neat cement is the least permeable of all; that concrete made with 700 lbs. of Portland cement, 1 cu. yd. of mixed sand, and 1¼ cu. yds. of small gravel, and moulded in the shape of a hollow cylinder with a shell 2½ ins. thick; was impermeable under a head of water of 13 ft., while a mortar made with the same amount of cement and sand, but without gravel, and moulded in the same way, was somewhat permeable. Under a head of water of 27 ft., the concrete was barely permeable, while the mortar of cement and sand was very easily permeated. Concrete made with 1 150 lbs. of Portland cement, 1 cu. yd. of mixed sand, and 1¼ cu. yds. of small gravel, mixed very accurately with the quantity of water strictly necessary to work it up (say ⅓ cu. yd. of water), was impermeable under a head of 40 ft.

The effect of exposure to wave action, the labor required in the construction of different kinds of masonry, and the adhesion of mortar to different materials, were also studied carefully in these experiments.

The latest paper on the subject is one by Messrs. J. B. McIntyre and A. L. True, on "The Permeability of Concrete under High Water Pressures," which was presented before the Thayer School of Civil Engineering in 1902, covering experiments made in January to March, 1902. In many cases these experiments were made under conditions quite similar to those of Messrs. G. W. Hyde and W. J. Smith, the apparatus being of the same general character, and the pressures being 20, 40 and 80 lbs. per square inch, the time of the test lasting two hours. Two brands of Portland cement were used, and mortars of 1 : 1, 1 : 2 and 1 : 3 of sand were made. The conclusions drawn from the experiments are as follows:

"From the tables it will be seen that several of the mixtures were practically impermeable to water at the pressures which we had at our disposal, nearly from 20 to 80 lbs. per square inch.

"All the specimens composed of 1 : 1 mortar in the proportion of 30, 35, 40 and 45% of the whole mass were impermeable. Some of the specimens composed of 1 : 2 mortar in the proportions of 40 and 45% were also impermeable, as well as the mixtures of 1 : 2 : 4 and 1: 2½ : 4.

"All others leaked at the high pressure, and in a general way may be said to have shown a degree of imperviousness in direct proportion to the proportion of mortar in them, with the lower pressures, as well as with 80 lbs. However, as the object was to secure an impermeable product, the greatest attention was devoted to those mixtures which withstood the high pressure. Mr. Lesley.

"In the tests it has been assumed that the amount of evaporation was the same in all cases, as the time was the same in all the tests, and the temperature practically constant. But, at the same time, it must be granted that there will probably be some error, owing to the different consistency of the specimens and other unavoidable irregularities.

"On account of this, it is not well, in drawing conclusions, to lay much stress on the amount of water absorbed during the test as affecting the quality of the concrete in question; that is to say, when the amount of water absorbed was only a few grams and the specimen showed no sign of leaking. In fact, on leaving the specimens under pressure for 24 hours, it was found that in almost every case the specimen was lighter after the test than before, evidently owing to evaporation.

"The temperature of the room was about 50° Fahr., and remained nearly constant, and the air was far from dry, there being several tanks of water in the room continually.

"The results show a decided advantage for the specimens made from cement No. 1, both as regards the amount of water absorbed during the test and ability to withstand the highest pressure without sign of leakage. It appears also more plainly from the fact that cement No. 1 was procured in the open market, while cement No. 2 was sent by the manufacturers, who knew the object of its use. However, No. 2 was said to be more than two years old, and thus might not have been a first-rate sample.

"The specimens which showed no leak in 2 hours were left under pressure for 24 hours, and at the end of that time no leak appeared in any case.

"As a pressure of 80 lbs. per square inch is equivalent to a head of 184 ft., and the thickness of the concrete was only 5 ins., it is perfectly safe to conclude that a concrete of the proportions of any of the specimens which did not leak under 80 lbs. pressure would be practically impermeable under any conditions ordinarily found in practice.

"Of the various mixtures, we may safely choose either 1 : 2 : 4 or 1 : 2½ : 4, on account of their simplicity and the ease with which they may be proportioned, either for hand or machine mixing. In extreme cases, however, it might be advisable to use one of the richer mixtures."

As far as these general experiments on the question of the permeability of mortars show, they indicate conclusively that neat cement mortars show the least permeability, and that mortars with fine sand are less permeable than mortars with coarse sand, and that the lessening of the permeability is due to the closing of the pores by lime in suspension, which is carried through in the process of filtration through the mass, which ultimately forms a coating on the face of the masonry.

This state of facts was shown rather clearly in experiments by the late Alphonse Fteley, Past-President Am. Soc. C. E., former Chief

Mr. Lesley. Engineer, New York Aqueduct. In order to make some of his masonry on the New York Aqueduct impermeable, he prepared a lime and cement wash with which the surface of the masonry was painted and which closed the exterior pores of the cement and made the work practically impermeable.

A practical illustration of Feret's experiments was shown in the case of a large concrete tunnel which was built at Hartford, Conn., where, after the construction, a large amount of efflorescence and small stalactites and stalagmites showed on the surface. Attention was called to this as a fault and defect in the masonry, but it was allowed to remain untouched, and the tunnel, though built in a particularly damp place, proved absolutely impermeable to water.

*The basis of all these various substances which it is suggested to add to mortars seems to be alum, fully as much if not more than soap. Alum has already been added in the making of hard plaster, and the material made is known as Parian cement, which is used in the manufacture of artificial marble and work of that kind, the addition of the alum forming aluminated sulphates of lime. Beds of natural Parian cement, as it might be called, have been discovered in Kansas, where silicated and aluminated sulphates of lime are found. These substances are water-proof, in which they differ from the ordinary plasters made of sulphate of lime alone.

It would seem that possibly a cement of that kind might be very finely ground and might be used for water-proofing impermeable mortars without introducing into mortars, soaps, alum or other substances, the chemical results of which are not thoroughly known in their bearing upon the duration of the mortar. It would certainly be a fatal thing to add an excess of alumina to the ordinary cement mortar where the use of concrete is to be in salt water. It would seem to the speaker that with these possible dangers, any change in the chemical constituents of the cement by the addition of new chemicals, the results of which are not known, is a subject that ought to be considered very carefully.

The fineness of the cement seems to be a very important feature in forming a coating to prevent permeability. It is known, from the examination of briquettes which have been kept in pans with water running through, that at early stages the briquettes when broken, even the neat ones, show considerable water through the entire mass; but, in the sand briquettes, the larger the admixture of sand, the larger the percentage of water. Now, when briquettes of neat cement are kept from month to month and from year to year, and are examined and broken, it is found that in the early stages there is a small core of dry material which forms in the center of the briquette—a small whitish-looking core which is absolutely dry—and as those neat briquettes are

* This part of Mr. Lesley's discussion was added after hearing the remarks of Messrs. Croes, Schaub, Green, Lowinson, Cunningham and Hatt.

kept for longer periods, and up to four, five or six years, it is found that that drying out or hardening from the center has continued and come out to the surface, while from the surface inward there seems to be hardly any percolation of water whatever. This is not the case with the sand briquettes. On the contrary, the core is formed much more slowly and takes much longer in coming to the surface. Thus, from this practical experiment it may be noticed—not under heads of water, but right under the ordinary flowing of the stream—that cement seems to take care of itself, as far as permeability is concerned, and largely in proportion to the fine grinding of the cement and the character of the coat that seems to be formed on the outside to repel the water; and the core that forms on the inside is largely dependent on the quality and the character of sand used. Mr. Lesley.

The speaker's theory and conclusions, based upon all that has been discovered, and especially upon Feret's remarkable experiments, would seem to indicate that the best addition to cement mortars for the purpose of making them impermeable, according to the theory of an exterior coating by lime carried through the mass during filtration, would be to add to the concrete, at the time of mixing, a reasonable proportion of hydrate of lime, or, in other words the ordinary slaked lime of commerce. This slaked lime, as has been shown by experiments of the late Professor De Smedt, formerly of the Laboratory of the District of Columbia, does not injure cements or mortars; does not cause expansion; and does not decrease their strength, though retarding their setting slightly. Such an addition would be perfectly safe, as a matter of practice, and would form in the mass a substance which would be carried by filtration and close the pores, form efflorescence or stalactites and stalagmites on the surface, and, in the speaker's judgment, though he knows of no experiments on the subject, would aid largely in making mortars impermeable. Experiments in this line would be most valuable.

J. James R. Croes, Past-President, Am. Soc. C. E.—The proposition for discussion is whether it is possible to make concrete which will be impervious to water. This is a very different thing from making an existing mass of concrete impenetrable by water. The latter requires only the application of an impenetrable coating to the surface of the mass. The former requires the entire interior composition of the mass to be such that water will not percolate through it at any point. Mr. Croes.

That a small mass of concrete can be made which will be entirely impervious to water, is incontrovertible. The question is, whether, in practice, a number of such small masses can be united in such a manner that the joints between them will be impermeable, also. Theoretically, there is no doubt that they can. Practically, the difficulty is in securing proper manipulation of the materials, at a reason-

Mr. Croes. able cost, and it is to be hoped that the discussion of the subject here will elicit descriptions of methods used by various practitioners in constructing large masses of concrete, and statements of the results obtained, both as to efficacy of the means used and the expenditure required to produce certain results.

But the mechanical combinations and the manipulation of the materials required to reduce the void spaces in a mass of fragments of different materials to a minimum and thus prevent the percolation of water, are not the only points to be considered. Chemical changes take place in materials thus compounded, and, of late years, studies have been made of the action produced by the introduction of other substances than stone, sand and water, into the composition of the mass which is to be made impervious, producing chemical action which reduces the porosity of the mass. It is to be hoped that anyone who has taken part in investigations of this kind will contribute to this discussion.

Mr. Cunningham's communication refers to an application of the Sylvester process, which was invented about sixty years ago and was used with success on the exterior of walls of buildings. It was applied to the gate-houses of the Croton Reservoir in Central Park, New York City, and is described in the *Transactions** of this Society. That was a wash of soap and alum applied to the surface of a brick wall to prevent the percolation of water through that wall. In the case mentioned by Mr. Cunningham the experimenter mixed all his materials together, that is, the soap, the water and the alum were put in as constituent parts of the mortar itself, and the chemical action, which in the case of the wash occurred only on the exterior of the wall, was made applicable to the whole interior.

In the case of the cellar mentioned by Mr. Lowinson, an impervious material was placed between the layers of concrete. That was not making concrete impervious to water, but was simply keeping the water away from the concrete.

The question is, can the concrete itself be made impervious, and it seems to the speaker that the experiment mentioned by Mr. Cunningham is a most interesting one, and one which is capable of further amplification. That is, of producing the chemical change in the constituents, so that when they are all mixed and placed together, the water will not penetrate them. Chemical action takes place in the whole of the wall, and, somehow or other, the pores are filled up by the addition of the soap and alum.

Now, can we not make a concrete which contains some materials which will act together chemically? The composition of concrete is purely, or almost entirely, mechanical. Can some substance be introduced into the concrete by which a chemical change will take place,

* *Transactions*, Am. Soc. C. E., Vol. I, p. 208.

which will make that concrete thoroughly impervious to water? This experiment indicates that such can be done. Mr. Croes.

Although masonry is impermeable to water, a crack may occur in it the same as in concrete. It is desired to make the concrete itself, in the mass, impermeable to water, but cracks cannot be prevented from occurring on account of unequal settlement, without very great care in construction. What is wanted is a material which, when made in a large mass, will be impermeable to water, provided it does not crack from unequal settlement, or expansion and contraction. Either wall or either material will be impermeable, but if a crack occurs, the water will go through it.

J. W. SCHAUB, M. Am. Soc. C. E.—In building an ordinary concrete cistern to hold water, all that is necessary to make the concrete impervious is to wash the walls inside with grout. Usually two coats of neat cement grout are sufficient for this purpose. This coating on the inside will hold the water in the cistern, but it is not impervious to water from the outside. In order to make a cistern impervious to water, inside and outside, it would be necessary to wash both sides, if possible, with grout. This is exactly what should be expected; the fine particles of cement closing up the pores of the concrete, similar to the caulking of the seams of a water-tank or boiler. In order to make a tank hold water it is necessary to caulk the seams from the inside; and, in order to make it impervious to water from the outside it is necessary to caulk the seams from the outside. The above applies to concrete when the water pressure does not exceed a head of, say, 10 ft. For pressures greater than that, the wash of grout does not suffice, and, in addition, the speaker has used asphalt, applied hot, with a mop, until a coat, ¼ in. thick, covers the grout, and the results have been entirely satisfactory. To what extent this can be carried, the speaker is not prepared to say, but he believes that a coating of asphalt ¼ in. thick, in addition to the grout, is sufficient for a water pressure of 60 ft., and he has recently specified this coating for this pressure. Mr. Schaub.

When the face of the wall to be waterproofed is accessible, it is a simple matter to apply the washes of grout and hot asphalt. If, however, the face is not accessible, the speaker knows of no method to be used to make that face impervious to water, excepting to build the wall in two parts, and fill the core or hollow space between the walls with asphalt. This method was used successfully in St. Louis, several years ago, in stopping leaks in a conduit, after every other method had failed. To be sure, a coating of asphalt is not permanent, but nothing is permanent in this world, and a coating of this kind, where exposed to the direct action of water, will have to be renewed about every ten years, the water acting on the asphalt as a solvent, as it does on everything else. Where the asphalt is used to fill up the cores in a wall, it will probably last as long as the wall.

Mr. Schaub. In case the concrete is reinforced with steel, it becomes almost necessary to make the concrete impervious to water, for it has been shown,* by M. Breuillé, a French engineer, that a chemical union takes place, between the metal and the cement, forming the silicate of iron, which is soluble in water. When this salt has been dissolved, the bond between the metal and the concrete is destroyed, and therefore the combination of the concrete and steel is no longer steel-concrete, but a conglomerate of two substances which have nothing in common, excepting, perhaps, their coefficient of linear expansion. M. Breuillé has also shown that, where concrete has been protected by means of an asphalt covering, this union or bond between the concrete and the steel has not been destroyed by the action of the water. The conclusion to be drawn, is, that the concrete should have a coat of asphalt, or some other form of waterproofing, in order to make it impervious to water.

The speaker would suggest that this question, together with the entire matter of steel-concrete, be referred to a Special Committee of this Society.

Mr. Green. B. R. GREEN, M. Am. Soc. C. E.—The question appears to be simple. Of course, it stands to reason that any concrete to be watertight must be so nearly solid—the interstices of the component materials or aggregates so well filled—that there shall exist in the mass no interstices or connected porosity, through which water can find its way from one side to the other. Most stones are permeable to water. It will soak into them. This is indicated by the tendency of some cements to stain stones that are embedded in or backed up with them, and by the earth stains found at greater or less depth in exposed rocks in nature. Building sand consists of very small stones. Even pure cement, after becoming indurated or set, will also soak water somewhat, especially if not ground to extreme fineness.

If, therefore, the materials of which concrete is composed are permeable to water, the concrete itself must be so, even if so well made as to be free from porosity or spaces between the stones, particles of sand, and cement. But, while water will soak through these materials, it is known that its progress is very slow, so slow that under slight heads of water thick and carefully built concrete walls will keep quite dry on the outside if exposed to drying air, the water evaporating as fast as it reaches the surface. This seems to be the whole story.

It would be very easy to determine by experiment the coefficient of soakage of pure cement for different thicknesses of wall and different heads of water, and the same for cement mortar with good quartz sand.

The speaker firmly believes that cement concrete can be made as

* *Annales des Ponts et Chaussées.*

water-tight as a stone wall, but not absolutely moisture-proof, without the application or insertion of a coating or core of some perfectly impervious material like asphalt. Mr. Green.

Oscar Lowinson, Assoc. M. Am. Soc. C. E.—About four years ago the speaker had an experience, recalled by the remarks of Mr. Green, in reference to the means by which concrete can be made water-tight. He tried to build a cellar on South Street, in New York City, which was to be made impervious to water against a head of about 6 ft. The building is located about 100 ft. from the dock line of the river. The intention was to put a damp-course on a properly prepared bed of 6 ins. of concrete; this course to be water-proof, and on top of the damp-course 18 ins. of concrete, this having been computed to be of sufficient strength to resist the upward pressure of the water. The cellar was about 48 x 70 ft. in area. The theory was that if the damp-course were not punctured, the only work the upper layer of concrete would have to do would be to act as a medium to resist the hydraulic pressure; however, lest a leak might occur in the damp-course, this top layer of concrete was to be made most carefully, it having been the speaker's opinion that the concrete in it would keep the water out. The speaker was present during the greater part of the time when this concrete was being mixed. The job was done continuously, and, in that manner, no unfinished edge was permitted to set. Some six weeks after the completion of the job a sweat appeared at the lowest part of the cellar, which had been graded so as to permit baling out in case water might gather. At the end of another week several pailfuls of water had gathered, and, from that time on, the water found its way into the cellar at the rate of about a pailful a day. There was no question but that the water-proofing had been punctured, and also that the water had found its way over the concrete, but what surprised the speaker and caused him to conclude that his ideas as to the imperviousness of any concrete required revision was, that when he went to trace the source of the stream the puncture was found 18 ft. from where the dampness appeared upon the surface. Several attempts were made to repair this leak, but with no success, and the whole was finally removed, with the exception of the bottom layer, which had served as a bed for the water-proofing. Mr. Lowinson.

This cellar was made over twice again with the same result, costing the contractor more than five times the amount of his contract. The cellar was built finally in a different way. On top of the water-proof layer, a layer of brick in a bituminous mortar was placed, and 15 ins. of concrete placed on top of the brick. This was successful, and the cellar is perfectly tight to-day. The concrete used for the layer was composed of 1 part Saylor's Portland cement, 2 parts Cow Bay sand and 4 parts small broken stone. The speaker believes that the stone was not greater than 1 in. in diameter. Then there was a 2-in. cream of Portland cement and sand floated on, for a finished surface. The

Mr. Lowinson. concrete was mixed to a consistency that caused it to sweat when thoroughly rammed.

The concrete was mixed as follows: The sand and cement were first mixed and wet, the wet broken stone was put on top, the whole turned three times and the entire batch put in place within thirty minutes from the time mixing began.

Some of the remarks made in reference to this subject bring to the speaker's mind a paper which he heard read last spring, by Mr. Maximilian Toch, at a meeting of the New York Section of the Society of Chemical Industry, on the preservation of materials of construction, in which was propounded a theory which so interested the speaker that he suggested to Mr. Toch that a like paper read before the American Society of Civil Engineers would be productive of considerable discussion and most likely lead to valuable results.

The theory advanced by him was this: A thin layer of very fine cement, entirely free from all the elements that cause or aid oxidation or disintegration, can be applied so that it will change the initial condition of the surface exposed to dampness, so that, instead of being porous, or exerting capillary action, the effect upon the moisture or water would be similar to the action of oil on water, causing a repulsive, instead of attractive, influence. Mr. Toch was assisted in the preparation of this paper by Clifford Richardson, Assoc. Am. Soc. C. E., and the results that they had attained made the speaker believe that the theory was quite plausible.

The matter referred to interests the speaker in his building work, and he has used this material since as a cement wash on the surface of a building in New York City. It has now been in place some three months, and, so far, it appears to have kept out the moisture where, before that time, dampness had penetrated. It differs from the ordinary cement wash in that it sets almost immediately, does not flake, and is not washed off by the rain.

There is a possibility that concrete can be made impervious to water or dampness by an application of this kind, and this is a matter worthy of the best study that can be applied to it. In order to make it impervious, it would be necessary to apply this wash on both surfaces of the concrete.

Mr. Cunningham. EDWARD CUNNINGHAM, Esq. (by letter).—The writer recently made some tests for water-proofing mortar, which, though crude, were entirely satisfactory.

Using the materials at hand, two vessels, having an internal diameter of 11¼ ins. and an outer diameter of 12 ins., and about 26 ins. deep, were made in the following manner: A sheet of "chicken wire" was rolled and wrapped with wrapping paper. This was placed on a square board and filled with sand, making a heavy core. A split 12-in. terra cotta side-collector pipe was used for an outer shell and placed about the core, leaving a space of approximately ½ in. between the core and

the pipe. This space was then filled with rather wet mortar, which was worked down by "ramming" with thin narrow sticks. When filled to the top, a bottom was formed over the sand core. Mechanically, the two vessels were as nearly alike as they could be made from such simple materials. The paper was not a so-called waterproof paper. The pipes were slightly greased before placing, in order to prevent the cement from sticking. Mr. Cunningham.

The mortar placed in the first vessel was of the ordinary 2 : 1 mixture, in which was used Allegheny River sand, as it came from the pile. The mortar for the second vessel contained the same proportions of cement and sand, with the addition of 1% of the weight of the sand and cement in powdered alum, and 1% of the weight of the water in yellow soap. The alum was mixed in the sand and cement while dry, and the soap had been dissolved in the water.

The difference in the texture of the two vessels, when taken from the forms, was very noticeable. The water-proofed vessel was fine-grained and close, and was much smoother to the touch than the other. Lids of roofing slate were "rubbed" on after putting a ring of neat cement around the top, in order to prevent evaporation.

After about three months the vessels were filled with water. The vessel made of the plain mixture immediately began to sweat, and "pin-holes" to weep. On damp days this was very noticeable. On dry, windy days the water on the surface of the vessel was apt to evaporate as quickly as it seeped through. The soap and alum vessel developed two or three "pin-holes," which showed slight weeping, otherwise it was dry. Without any records, the writer's recollection is that while the plain vessel was losing about 12 ins. the other vessel lost about 1 in., and that was through the "pin-holes," the surface never appearing generally damp.

In plastering the inside of a covered clear-water well, a potash soft-soap was used. The water for the plaster was used from a barrel into which 1¼ lbs. of soap was put for each five buckets of water. The alum was used from paper bags by the mixers, a bag of alum to a bag of cement. As the walls leaked badly the contractor did this part of the work conscientiously. The mortar was fine to handle with the trowel, but the masons, frequently nauseated by the odor, had to come out to ventilate themselves.

Two plastering coats were applied, both being not more than ½ in. thick. The writer's instructions were simply to cover up the stone and make no attempt to bring it to a surface. There was seldom more than ¼ in. in the coating.

The results were entirely satisfactory. The application was made when there was no leakage; and, when rains set in, in the fall, the walls remained almost entirely dry.

In the filtered-water regulating houses the 18-in. dividing wall showed no leak when one side held 16 ft. of water. In the clear-water

Mr. Cunningham. well there was slight leakage at the joint between the work from the floor, and that from the scaffold.

There are some soaps in which the potash is much stronger than in others. The "old-fashioned" soft-soap, made on the farms, from soap fats and wood ashes is one kind of potash soap, and has a dark color because clean fats are not used. The soap used by the writer was white, because made of clarified fats, and was expensive—7½ cents a pound—but should be obtained for much less. It came in bulk, in barrels.

Using 1 part cement to 2 parts sand, it takes from two to three 12-quart buckets of water for each barrel of cement to mix mortar to troweling temper. Concrete requires from six to eight buckets of water. The wetness or dryness of the sand (except the very extremes) may be disregarded, as laborers will vary the quantity of water, from batch to batch.

Lehigh cement is put up in bags of 96 lbs. each. When mortar is mixed in the proportions of 2:1 there will be approximately 100 lbs. of cement to 200 lbs. of sand, therefore the alum was put up in 3-lb. bags, and one bag of alum was used with each bag of cement.

Therefore it takes 3 × 4, or 12 lbs. of alum to each barrel of cement in 1 : 2 mixtures.

The extra cost would be:

Soap, 2 lbs. (with 8 buckets, or 200 lbs. of water) at 7½ cents	15 cents.
Alum, 16 lbs. (with 1:3 mixtures) at 3½ cents	56 "
Extra cost per batch of concrete	71 "

In a concrete proportioned 1:3:5, each batch will make about 0.75 cu. yd. of masonry in place. At that rate, the extra cost would be, approximately, $1 per yard. But both soap and alum, in larger quantities and in grades not as fine, should be obtained for much less money.

The writer, however, does not believe that it is at all necessary to build a concrete wall in this manner, as a 2-in. mortar face should be ample. In the filtration works at Apollo, a skin averaging less than ½ in. in thickness seemed to be sufficient.

Mr. Hatt. W. K. Hatt, Assoc. M. Am. Soc. C. E.—Various solutions have been used to render concretes water-tight, or to protect stonework. Some of these solutions form the basis of patents granted for the manufacture of artificial stone. The speaker has experimented with two of these: silicate of soda, and alum and soap. The silicate of soda, called water-glass, is used locally in Northern Indiana as a surface coating for reservoirs and water cisterns. The soap and alum solution has been used for some time, as alternate coatings for the surface of masonry, under the name of Sylvester's wash.

Mr. Hatt.

Alum forms the hardening agent of many patent mixtures for making artificial stone. One patent, granted in 1876 to L. L. Leathers, for artificial stone, * prescribes a mixture of cement and sand moistened with a solution formed of a mixture of fat and lye with alum.

The speaker was confronted a few years ago with the problem of designing a mortar for use in forming the segments or plates out of which burial vaults are moulded. These burial vaults must be water-tight, and since the expense of freight soon limits the area to which shipments may profitably be made, the mortar should be as light as possible. The conditions were met by a design of a mortar of 2 cement, and 5 fine bituminous ash made into plates strengthened by ordinary poultry mesh. Experiments were conducted with silicate of soda, and with the alum and soap solutions, to determine the effect of these on the strength and porosity of the mortar. The following results, in general, are of interest.

The effect of silicate of soda is to diminish the strength of both ash and sand mortars more than 50%, and to diminish the absorption of the ash mortars about 50 per cent.

The effect of alum and soap mixed in with the mortar at the time it is gauged is to strengthen and harden the ash mortar about 50% and to diminish its absorption by 50 per cent. A soap solution alone will diminish the absorption (by the action of the alkali in the cement on the soap) but will not increase the strength.

The strength of the sand mortar is not greatly affected by the soap and alum, but its absorption is decreased about 50 per cent. The effect on the absorption was measured by comparison of the weight of water taken up by briquettes which were immersed after having been dried out. Check tests were made by measuring the water which percolated from the outside through the walls of hollow cylinders.

The speaker believes that this is the first use of a soap and alum solution for waterproofing, in place of the usual gauging water.

The method used by the speaker is as follows: A 5% solution of ground alum and water is prepared; and a 7% solution of soap and water. The alum solution is mixed with the mortar to the amount of one-half the ordinary gauging water. The soap solution is then applied in amount to bring the mortar to the desired plasticity. The soap and alum, acting together, cause the precipitation of an insoluble compound in the pores of the mortar.

A solution of lye and alum is said to produce the same effect.

In regard to the problem of making pipes, the French engineers believe that in order to make a concrete pipe hold water, a sheet-iron tube must be placed inside of it when the head is about 50 ft., and such pipes have been used under a head of 300 ft. When the head is less than 50 ft. they make a reinforced concrete pipe without any steel lining.

* Letters Patent No. 178 307.

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PAPERS AND DISCUSSIONS.

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AUTOMATIC MODULES FOR REGULATING THE SPEED OF FILTRATION.

Discussion.*

By Messrs. W. R. COPELAND and J. W. HILL.

Mr. Copeland.

W. R. COPELAND, Assoc. Am. Soc. C. E. (by letter).—In his discussion on automatic modules, Mr. Gregory describes† the automatic weirs which are used to regulate the rate of filtration at the Roxborough filters in Philadelphia.

By glancing at the diagrams which are given on page 563† it will be seen that the weirs have the following points in common: They are supported by floats which rise and fall with the level of the water in the filtered-water chambers; they consist of pipes which are held in a vertical position by spiders attached to the floats; the lower part of the weir pipe slides up and down in a casing, and for that reason it is designated a "telescopic" pipe; the water in the filtered-water chamber escapes from that chamber by running over the edge of the weir, passing down through the telescopic pipe and out into the effluent mains.

The principal differences in the designs of the "regulators" are as follows: At Lower Roxborough the effluent mains are fastened directly to the bottom of the casing in which the telescopic pipe slides, whereas at Upper Roxborough the effluent pipe leads off from the side of the casing; moreover, the water drops farther at Lower than at Upper Roxborough.

In falling, the column of descending water creates a partial

* Continued from the *Proceedings* for May, 1903. See February, 1903, *Proceedings* for paper on this subject by Charles Anthony, Jr., M. Am. Soc. C. E.

† *Proceedings*, Am. Soc. C. E., for May, 1903.

vacuum. In order to prevent this, air rushes into the telescopic pipe, both at the center and behind the sheet of water. A portion of this air mixes or becomes "entrained" with the water, and, under certain conditions, passes out through the bottom of the telescopic pipe into the effluent mains. Mr. Copeland.

Commenting upon this feature of the action of the automatic weir, Mr. Gregory says:

"It was expected, however, that there would be some entrained air carried along in the solid column of water passing down through the telescopic pipe, due to the agitation at the surface produced by the falling sheet of water. * * * It seems * * * that there has been some little trouble caused by air being sucked in."

The "trouble" to which he refers arose from the formation of a water hammer which was so severe that a large valve on the outlet of the filtered-water main had to be taken off, in order to prevent the "hammer" from breaking the pipe joints. This is not the first time that trouble has been caused by automatic regulators of these general design. In 1898 the Filtration Commission of Pittsburg* made some experiments in water filtration with a mechanical filter of the so-called "Warren" type.

As at Roxborough, the Warren regulator consisted of a float supporting a weir, but in this case the weir was made of an "orifice" plate set in the top of the telescopic pipe, and the water entered the pipe through this orifice. Air was sucked in by the sheet of falling water at the center, and through air-pipes tapped into the top of the telescopic pipe just below the orifice plate. See Fig. 15.

The column of water falling downward sucked in air to a considerable degree, as is shown in the following statement:†

"It was found necessary to allow an abundance of air to enter the top of the central pipe of the automatic weir, to prevent a vacuum from being formed and thus cause the float and orifice to drop, causing too much water to flow. The entrance of the air, however, caused serious over-registration of the (water) meter upon the effluent pipe; the error occasioned in this way reaching 13% of the volume of water filtered. After a trial of various devices, vents were arranged which reduced the error to 4 per cent."

The vents referred to are shown on the right of Fig. 15,‡ and were three in number. The largest, 6 ins. in diameter, was placed on top of an elbow in the effluent pipe just before the meter. The other vents were smaller and were placed on top of the meter in order to release the air which passed by the 6-in. vent.

Although some air was sucked in through the air-pipes, the volume was small. It produced a vacuum of about 2 ins. on a mercury column. Therefore the air entrained at the central well created most of the trouble.

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* "Report of the Filtration Commission," Pittsburg, 1899.

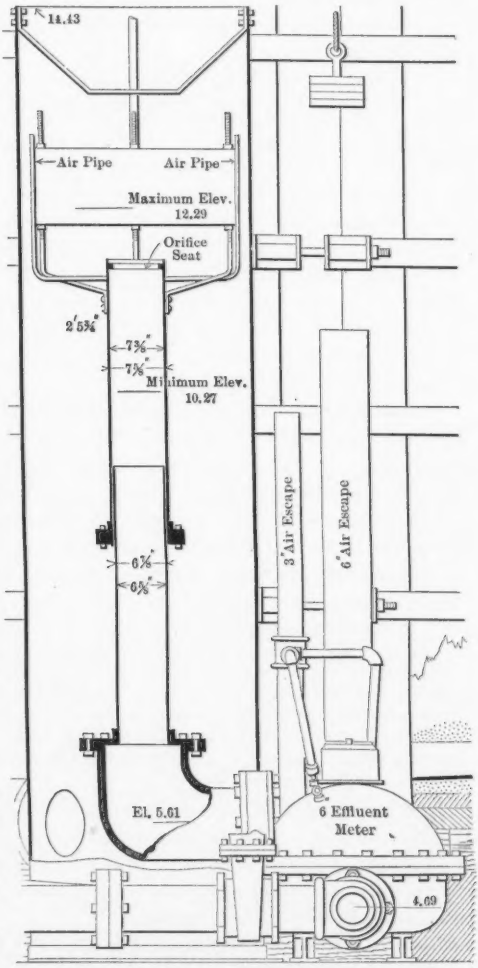
† "Report of the Filtration Commission," Pittsburg, p. 158.

‡ Report of the Pittsburg Filtration Commission, Plate No. 16.

Mr. Copeland. The volume of air entrained by an automatic regulator will depend upon several factors.

As the air is sucked in because of the downward draft caused by the falling sheet of water, the distance which the water falls is an important factor in the process of entraining air. Advantage is taken of the fact that the "draft" varies with the distance which the water falls in developing power by turbines.

The manner in which the water is drawn away from the bottom of the telescopic pipe is another important factor. If, for instance, the telescopic pipe discharges directly into an effluent main which has considerable slope, or upon which so much draft is made that the water is "drawn" out of the lower part of the casing with great rapidity, the pipe will be emptied to the very bottom. In consequence of this, air, forced into the telescopic pipe by the downward rush of the falling sheet of water, will be driven into the effluent main.



WARREN AUTOMATIC WEIR

FIG. 15.

But, if the telescopic pipe discharges into a chamber which is arranged in such a manner that the effluent main does not draw the water away immediately from the telescopic pipe, the downward current will be checked before the water enters the main. As a result, the level of the water will tend to rise in the telescopic

pipe, shortening the fall and preventing the entrained air from being forced into the main to a considerable degree. Mr. Copeland.

The volume of air entrained by the Warren filter, as pointed out in a former paragraph, was measured accidentally. The air entrained by the Roxborough regulators has never been measured, but, in order to give an idea of the probable action of these weirs, data prepared for the Warren and Roxborough filters have been placed in Table No. 2 for comparison.

TABLE No. 2.

Regulator designed for:	Maximum distance through which the water falls (in feet).	Rate of flow through the telescopic pipe. Linear feet per second.
Warren Filter	6	0.23
Lower Roxborough	15	0.31
Upper Roxborough	7.7	0.41
Torresdale (Special)	2	0.41

From the figures given in Table No. 2 it is evident that the "length of fall" and the "rates of flow" are greater at the Roxborough filters than they were for the Warren filters. Therefore, it would be natural to expect that the volume of air entrained would be greater at Roxborough than at Pittsburg. The air entrained at Lower Roxborough is so considerable in volume that the theoretical deduction seemed to be borne out in practice. But, at the time of writing, no such results have developed at Upper Roxborough. These filters, however, have not yet been given a test at their maximum "working" rate of filtration.

By comparing the diagrams of the Warren and Lower Roxborough filters, one notes that the methods of drawing the water away from the telescopic pipes are the same, namely, by direct discharge into the effluent mains. The telescopic pipe at Upper Roxborough discharges into an "outlet casting," *D*, and the effluent main leads off from this casting at a point several feet above the point of discharge.

Whereas, then, the water is taken away from the Lower Roxborough telescopic pipes by what may be called "direct" discharge, the water is taken away at Upper Roxborough by what may be called an "indirect" or "trapped" discharge.

Instead, therefore, of forcing the entrained air directly into the effluent main, as at Lower Roxborough, the trap at Upper Roxborough gives the air a chance to separate from the water before it enters the effluent main.

Moreover, no matter at what rate of filtration the lower system may be operating, the steep slopes and arrangement of the effluent mains will always draw the water away to the bottom of the outlet

Mr. Copeland. casting, but when the filters run at low rates of filtration at Upper Roxborough and the filtered-water reservoir is full, the traps will "back" water up in the telescopic pipes of the regulators until the fall is shortened to only about 2 ft.

As the experience at Upper Roxborough, up to the present time, has indicated that with a fall of 2 or 3 ft. only, a small volume of air will be entrained, it is probable that the special form of regulator designed for Torresdale will reduce, to a considerable degree, the quantity of air entrained.

The diagram of the special regulator shows, however, that the telescopic pipe is very short, and that the effluent pipe occupies the larger part of one side of the outlet casting. Therefore, the discharge from this regulator is direct, and any air entrained by the column of falling water will be forced into the effluent main, just as it is at Lower Roxborough.

As Mr. Gregory states, the entrained air does not affect the efficiency of the filters. In fact, Mr. John W. Hill suggests that the aeration which this air will produce may be a benefit. But the action of the air on the valves and pipe lines is a danger which can be removed only by getting rid of the air.

Part of the air can be released by vents, but the experience with the Warren filter at Pittsburg showed that the escape pipes having an area greater than the effluent main failed to remove all the air entrained by the Warren automatic regulator.

Therefore, it is probable that vents placed on the top of the "outlet casting, *D*," would remove part but not all of the air entrained by the weir. In order to get rid of the remainder of the air it seems to the writer that the diameter of the first length of the outlet main should be increased to double its present size, and a large vent placed on top at the outlet end.

By increasing the diameter of the pipe the rate of flow through the pipe would be decreased, and a better chance be given for the air to separate from the water.

The entrained air escapes from the water just as soon as it reaches the clear-water reservoir. But if it should ever become necessary to "by-pass" the reservoir, delivering the water directly into the city mains, it is probable that the air entrained by the automatic floating weirs might break some of the joints in the pipes.

In order to prevent this, the floats can be forced under water until the weirs are submerged deep enough to prevent air from being sucked in at the center of the regulators.

When the weirs are submerged in this manner no way is left to control the rate of filtration except by opening the hand-valves a known number of turns. Even then the rates are likely to fluctuate directly with the variation in the consumption of the water. As irregular rates

of filtration are likely to interfere with the processes of purification, it is very desirable to install regulating devices which will reduce "personal superintendence" as much as possible. Mr. Copeland.

Therefore, if controllers can be made which will run automatically for twelve or fifteen hours, and if, as Mr. Gregory suggests, the controllers are brought from several filters into one house, the regulation of the rates of filtration can be kept in the hands of the engineer in charge of the plant.

JOHN W. HILL, M. Am. Soc. C. E. (by letter).—The experience with plain sand filtration in Philadelphia, at the testing stations located on the Schuylkill and Delaware Rivers, and at the Roxborough filters, indicates that it is extremely desirable that filters should operate at a uniform rate of percolation per unit of area per day. Oddly enough, it is sometimes shown that a rapid reduction of the rate of filtration is accompanied by an increase in the bacterial content of the effluents of the filters, and that at times when the rates are increased materially the bacterial content diminishes with the increased rate. These are phenomena which are still to be investigated to determine the true causes of what would appear to be anomalous results. Mr. Hill.

There is one serious defect in the floating circular weir, used to regulate and measure the rate of flow from the Philadelphia filters, as pointed out in one of the discussions on this paper, *viz.*, the very large quantity of air carried into the effluent pipes by induction or suction of the annular column of water flowing down the telescoping weir pipe.

All the plans for the Philadelphia filters contained, on the end of the effluent pipe, where it enters the clear-water basin, an automatic balanced valve, intended to adjust the rate of flow from the filters to the clear-water basin in such a manner that variations in the elevation of the water in the basin would cause corresponding variations in the rate of discharge from the filters (and gradually increase or diminish the rate of flow from the filters), to adapt the work of the filters to the requirements of consumption; but the large quantity of air carried down the telescoping effluent weir pipes rendered impossible the use of the regulating balanced valve at the clear-water basin, as intended. Steps are now being taken to substitute for the floating weir an adjustable submerged orifice, the depth of submergence of the orifice remaining constant while the area of the opening will be adjustable to the varying rates of flow of the filters. It is expected that the change, in this direction, will avoid the introduction of the large volume of air which now passes through the effluent pipe along with the water, and not only interferes with the proper operation of the main effluent regulator, placed at the end of the effluent pipe in the clear-water basin, but, to a material extent, diminishes the capacity of the effluent pipes, and causes a greater loss of head, in effecting the discharge of the filtered water from the filters, than is desirable.

Mr. Hill. It is not known that the induction of air constitutes any other disadvantage than the one above mentioned. If it were not that the air is in contact with the water in the effluent pipe for so short a time it might be said that the aeration of the filtered water flowing over the lip of the weir would be an advantage; certainly it could not be considered a detriment, although in this manner it is possible that air organisms may be drawn into the water and appear in the cultivation of samples of water taken from the clear-water basin for analytical purposes.

With reference to an automatic module, or effluent regulator, there is no doubt of the desirability of having a device which will adjust itself to the increasing loss of head in the operation of the filters, and maintain a constant discharge of water from the filters, but, unless such a device is absolutely reliable, there is a question whether the adjustable weir at Berlin, or the adjustable orifice used in the Hamburg and in the Albany filters, would not be preferable to the automatic regulator, the former compelling attention upon the part of the filter attendants, and a constant adjustment of the weir or orifice to the fixed rate of operation of the filter.

In the original form of the Lindley floating weir used in the Warsaw filters, the same trouble was found that is now being found with the Philadelphia effluent regulators, and recent information from Mr. I. Lindley, of Warsaw, shows that the original form of automatic regulators has been superseded by a form, containing an adjustable orifice placed below the surface of the water, with more satisfactory results in the operation of the automatic regulators.

It is the practice, in the works of the East London Water Company, to regulate the flow of water to and from the filters by valves adjusted by hand; but the rate of percolation is influenced directly by the draught of water by the pumps, pumping into the distributing reservoirs from the small clear-water basin into which the effluents from the filters are discharged.

The packing designed for the telescoping tubes of the Philadelphia effluent regulators was first a plain stuffing-box, and later a water-packed bronze gland through which the telescoping tube moved up and down. It was found that the leakage, however, when the packing was adjusted for the free movement of the telescoping tubes, was too great to admit of considering the automatic weir as a device for the measurement of the rate of flow from the filters, and in due time the original packing devices were removed and self-adjusting cup-leather packings substituted, which now allow the floats to respond promptly to slight changes in the water level in the effluent chambers, and maintain a reasonably constant head on the circular weir at the top of the telescoping tube.

The flow over the weir, for any adjustment, is determined very

accurately by stopping the flow of water into the filters, and noting the decline of head over the sand bed for a period of twenty minutes or half an hour, from which loss of level, and the known area of the filter tank, the rate of percolation is determined, and the weir rated for discharge accordingly. Such measurements are made conveniently for each adjustment of the head on the weir, and as long as the depth of flow over the lip of the weir remains unchanged, the weir may be accepted as a reliable means of measuring the discharge of the filter, as well as maintaining a constant rate of percolation through the sand bed. Mr. Hill.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final Publication.

CHARLES EDWARD HENRY CAMPBELL,* M. Am. Soc. C. E.

DIED DECEMBER 6TH, 1902.

Charles Edward Henry Campbell, son of James and Mary Rose (Buxton) Campbell, was born at Summerside, Prince Edward Island, Canada, on January 7th, 1850. His father, who was of Scotch descent, was a native of Prince Edward Island, but his mother came from England, being a member of an old Derbyshire family.

Charles Campbell was educated at Prince of Wales College, Charlottetown, Prince Edward Island. At the age of twenty he went to Schuyler, Nebraska, where he learned the business of bridge building, first in the field as one of the erecting crew, and afterward in the office.

In 1874 he moved to Council Bluffs, Iowa, where he formed a partnership with Mr. E. W. Raymond, under the firm name of Raymond and Campbell, for the purpose of building bridges. The partnership continued until the end of 1886, and during its existence the firm built a great many highway bridges and viaducts throughout the western States, besides a number of structures for several railroads, among others the following:

Council Bluffs and St. Louis; Humeston and Shenandoah; Burlington and Missouri; Kansas City, St. Joseph and Council Bluffs; Minneapolis Union; Northern Pacific; St. Paul and Duluth; St. Louis, Des Moines and Northern; Cheyenne and Northern; Fremont, Elk Horn and Missouri Valley.

During 1887, 1888 and 1889 Mr. Campbell was western agent for the Milwaukee Bridge and Iron Works, when, among other structures, he built the Twenty-third Street Viaduct in Denver, Colorado; rebuilt the bridge over the Missouri River at Ft. Leavenworth, Kansas; erected a bridge over the Missouri River at Ft. Benton, Montana, and constructed several large bridges and viaducts in western cities.

In 1889 he formed a partnership with Mr. J. B. Marsh, of Des Moines, Iowa, under the name of Campbell and Marsh, as western agents for the King Bridge Company, of Cleveland, Ohio. This partnership lasted until 1892, and during its continuance the firm built a number of bridges for the Kansas City, Pittsburg and Gulf Railway, an elevated railroad in Sioux City, Iowa, and a Missouri River bridge at Cascade, Montana.

* Memoir prepared by J. A. L. Waddell, M. Am. Soc. C. E.

In 1889 he was retained as consulting engineer to design and superintend the construction of a bridge, about 1 000 ft. long, over the Loup River at Columbus, Nebraska.

In 1892 he took again the agency of the Milwaukee Bridge and Iron Works, retaining it until 1895, when his contract expired. During this time, among other works, he built the temporary portion of the Omaha Bridge and Terminal Railway Company's bridge over the Missouri River between Council Bluffs, Iowa, and East Omaha, Nebraska.

From 1896 until his death he was engaged in contracting on his own account, constructing numerous small bridges in various places and a depot building for the Burlington road at Creston, Iowa.

In 1899 he was associated with Mr. James Saguin, in the construction of bridges for the Illinois Central Railroad Company near Council Bluffs, Iowa; and in 1901 he built a steel bridge over the Missouri River near Winston, Montana, and a combination bridge over the Snake River at Shelley, Idaho.

In 1885 Mr. Campbell married Miss Fannie Reeve, of Cleveland, Ohio, and she survives him. He left no children.

He was a prominent Mason and Knight Templar, and took great interest in everything relating to these societies, having held in them several high offices.

He was eminently of a genial and kindly nature, and won to himself many friends, who mourn his death sincerely. His business dealings were ever characterized by the utmost fairness; and he would have been a richer man, financially, had he made a practice of treating others as others treated him; but his disposition was rather easy going, so that he often failed to obtain his just dues, preferring to yield to others rather than to strive unpleasantly for his rights.

Had he been in any other line of the profession than highway-bridge contracting, he would have made his mark as a designer, for he often evolved excellent details to meet special conditions; but he had to make a living out of his business, and he could not do that and at the same time live up to his ideas in designing. He often complained bitterly of this. Occasionally, he had some small chance to show what he was capable of doing as a designer; but in most cases, even in his railroad-bridge work, there were restrictions of a financial character that prevented him from accomplishing anything out of the ordinary.

When given a contract, he generally managed to spend more money on the work in improving the character of the structure than he had originally estimated; consequently, he failed to become rich.

When allowed an opportunity to build first-class constructions, he always availed himself of it and succeeded in obtaining structures far above the common. For instance, the temporary piers, spans and

trestles of the Omaha Bridge and Terminal Railway Company's bridge over the Missouri River at Council Bluffs are as fine a piece of timber construction as was ever built in America. The work has already outlived its allotted time by two years, and could be relied upon to last several years longer, were there any necessity therefor. It is now being replaced with permanent construction, so that within a year this fine monument to Mr. Campbell's great constructive ability will no longer exist.

His death was due to a complication of diseases, resulting finally in Bright's disease. For more than a year he struggled bravely, almost without hope, and attended to his work long after he was too ill to go to his office or even to leave his chair.

He was a thoroughly good fellow, a true sportsman, an honest gentleman, and a broad-minded citizen, as well as a contracting engineer of high repute. His death at the early age of fifty-three is a loss to the engineering profession and to the citizens of the Middle West, among whom he was so extensively and favorably known.

Mr. Campbell was elected a Member of the American Society of Civil Engineers on October 3d, 1883.

PAUL DAVIS CUNNINGHAM,* Assoc. M. Am. Soc. C. E.

DIED JULY 13TH, 1901.

Paul Davis Cunningham was born in Monroe County, Georgia, on November 27th, 1869.

He was an undergraduate of Emory College, Oxford, Georgia. From July to September, 1887, he was a Rodman on surveys for the Atlanta and Florida Railroad, and then, until February, 1888, Assistant to the Resident Engineer on the construction of that road. From April to December, 1888, he was Rodman and Leveler on surveys for the Tennessee Midland Railway. From April to October, 1889, he was Leveler on surveys for the Cumberland Valley Extension of the Louisville and Nashville Railroad, and, then, until February, 1890, Assistant to the Resident Engineer on the Big Stone Gap residency of that road. In June, 1890, he became Resident Engineer on the construction of the Decatur, Chesapeake and New Orleans Railroad, where he remained until September of that year. From October, 1890, until March, 1891, he was Resident Engineer on the construction of the Clarksville Mineral Branch of the Louisville and Nashville Railroad. He was next engaged as Leveler on the survey of the Upper Tennessee River for the Engineer Department, U. S. A., which work occupied his time from May to October, 1891. From February, 1892, until February, 1894, he was Transitman in charge of one of the topographical parties of the International Boundary Commission between the United States and Mexico, and from August to October, 1894, he was U. S. Assistant Engineer in charge of remeasurements under that Commission. From October, 1894, to March, 1896, his position was that of U. S. Assistant Engineer on the International (water) Boundary Commission, United States and Mexico, and then he became Engineer Clerk in the Southwest and Northwest Divisions of the Engineer Department, United States Army, which position he held until June, 1898. From July to September, 1898, he was Assistant Engineer with the Chief Engineer on the staff of the Major General commanding the Army in Porto Rico. He then became Principal Assistant Engineer, Department of Havana, Cuba. In 1899 he was Acting Chief Engineer in the latter department, and in December, 1899, became Chief Engineer of the City of Havana.

On July 10th, 1900, Mr. Cunningham, then in Havana, received the following telegram from General Anson Mills from Washington:

"May I recommend you for Consulting Engineer, Boundary Commission, salary thirty-six hundred a year and expenses?"

On July 14th he received the following telegram:

"You have been appointed Consulting Engineer, Mexican Water Boundary Commission, subject to acceptance of your resignation as

*Memoir prepared by E. C. Lewis, M. Am. Soc. C. E.

Assistant Engineer and Superintendent, Havana Engineering Department, by Military Governor of Cuba. I start for El Paso to-day. Hope you will join me as soon as practical.

"ANSON MILLS, Commanding."

Mr. Cunningham joined his corps in August, 1900. He was Chief of Party for the International Boundary Commission, his work being to follow the course of the Rio Grande from El Paso to the Gulf, a distance of thirteen hundred miles. The voyage was deemed hazardous, and for half the distance the party would be cut off from all communication with the rest of human kind.

He was drowned in the rapids of the Rio Grande, below Eagle Pass, on Sunday, July 13th, 1901, and his body was not recovered until the next Tuesday. The remains were brought to Nashville, Tennessee, and then taken to Shelbyville, where, on July 19th, they were laid to rest by the side of his mother, in beautiful Willow Mount Cemetery.

"Death loves a shining mark." Never was this adage more fully exemplified. Paul D. Cunningham was a shining mark in life and for death. Born of most worthy parents, given all the advantages the American youth desires or requires, he reached manhood thoroughly equipped for the battle of life. Cultured, refined, considerate, of splendid manner and attractive person, with fine social, professional and official position and an unsullied escutcheon, what a shining mark he was—so shining that death struck him, a long way off, full fifty years before his time.

Paul Davis Cunningham was elected an Associate Member of the American Society of Civil Engineers on March 1st, 1899.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 7.

SEPTEMBER, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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NEW YORK 1903.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS in the office of the Librarian of Congress, at Washington.

American Society of Civil Engineers.

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Vice-Presidents.

Term expires January, 1904:	*Term expires January, 1905:*
CHARLES C. SCHNEIDER	L. F. G. BOUSCAREN.
JOHN R. FREEMAN.	JAMES D. SCHUYLER.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1904:	*Term expires January, 1905:*	*Term expires January, 1906:*
JOSIAH A. BRIGGS,	RICHARD S. BUCK,	ALFRED CRAVEN,
GEORGE F. SWAIN,	GEORGE H. PEGRAM,	JOSEPH O. OSGOOD,
EMIL KUICHLING,	WILLIAM J. WILGUS,	GEORGE S. DAVISON,
MORDECAI T. ENDICOTT,	WILLIAM JACKSON,	E. C. LEWIS,
EDWARD C. CARTER,	EDMUND F. VAN HOESEN,	HUNTER McDONALD,
FRANK C. OSBORN.	JAMES L. FRAZIER.	ELWOOD MEAD.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOSIAH A. BRIGGS,	GEORGE H. PEGRAM,	CHARLES C. SCHNEIDER.
L. F. G. BOUSCAREN,	ALFRED CRAVEN,	MORDECAI T. ENDICOTT,
GEORGE F. SWAIN,	JOSEPH O. OSGOOD,	EMIL KUICHLING,
RICHARD S. BUCK,	FRANK C. OSBORN,	WILLIAM JACKSON,
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Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 533 Columbus
CABLE ADDRESS, - - - "Ceas, New York."

Vol. XXIX. SEPTEMBER, 1903. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

September 2d, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 70 members and 12 guests.

The minutes of the meeting of June 3d, and of the Business Meeting of the Annual Convention at Asheville, N. C., on June 9th and 10th, 1903, were approved as printed in *Proceedings* for August, 1903.

The Secretary brought to the attention of the meeting a resolution, by J. W. Schaub, M. Am. Soc. C. E., which had been passed at the meeting of June 11th of the Annual Convention, as follows:

"It is the sense of this meeting that a Special Committee be appointed to take up the question of concrete and steel-concrete, and that such committee co-operate with the Association for Testing Materials, and the Railway Engineers' Maintenance of Way Association, which also have a committee on this subject."

The Secretary then moved, on behalf of Mr. Schaub, that a Special Committee on Concrete-Steel be appointed, and the matter referred to the Board of Direction. (Art. VI, Sec. 12 of the Constitution.)

The motion, being duly seconded, was adopted by a vote of more than twenty-five Corporate Members.

A paper, entitled "An Experimental Study of the Resistances to the Flow of Water in Pipes," by Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E., was presented by the Secretary, who also read communications on the subject from Messrs. A. Flamant, Hiram F. Mills, E. C. Thrupp and Allen Hazen.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

George Samuel Hayes, New York City.
Richard Carmichael Hollyday, Brooklyn, N. Y.
Leonard Metcalf, Boston, Mass.
Olaf Einar Mogensen, St. Louis, Mo.
William Babcock Poland, Cincinnati, Ohio.
Horace Ropes, South Framingham, Mass.

As Associate Members.

John Yancey Bayliss, Bardstown, Ark.
James George Beach, Philadelphia, Pa.
Charles Edward Fraser, New York City.
Julian Hastings Granbery, Elizabeth, N. J.
Arthur Newhall Johnson, Baltimore, Md.
James Augustus Kelley, Hedgesville, W. Va.
Clifford Lewis, Jr., Utica, N. Y.
Elbert Clyde Macy, St. Paul, Minn.
Nicholas Daubeney Monsarrat, Columbus, Ohio.
Joseph Edgar Murphy, Galesburg, Ill.
Charles Frederic Parker, Mapimi, Durango, Mexico.
Charles Marcellus Pritchett, Washington, D. C.
William Everett Swift, Washington, D. C.

The Secretary announced the election of the following candidates:

By the Board of Direction on September 1st, 1903;

As Associate.

Maximilian Toch, New York City.

As Juniors.

John Henry Burgoyne, Jr., Buffalo, N. Y.
Silas Stewart Feeter, Little Falls, N. Y.
Carl Hugo Jabelonsky, New York City.
Clarence William Meyers, Ithaca, N. Y.
John Endicott Porter, Danvers, Mass.
Alfred Francis Sauer, Elizabeth, N. J.
James Lloyd Tatlock, New Rochelle, N. Y.

On Reconsideration Ballot canvassed by the Board of Direction September 1st, 1903:

As Member.

Frank Churchill Horn, Cheesman, Colo.

The Secretary announced the following deaths:

Alphonse Fteley, Past-President, Am. Soc. C. E., elected Member January 5th, 1876; President, January 19th, 1898, to January 18th, 1899; died June 11th, 1903.

George Shattuck Morison, Past-President, Am. Soc. C. E.; elected Member January 5th, 1875; President, January 16th, 1895, to January 15th, 1896; died July 1st, 1903.

Charles Cyril Martin, elected Member July 10th, 1872; Vice-President, 1894–1895; died July 11th, 1903.

Charles Frederick Dunham, elected Member April 2d, 1902; died June 13th, 1903.

Frederick Winn Bond, elected Member December 7th, 1898; died July 12th, 1903.

Eugene Vanderpool, elected Member September 2d, 1874; died July 12th, 1903.

Cornelius Palmer, elected Member November 2d, 1887; died July 31st, 1903.

Sylvanus Thayer Abert, elected Member September 21st, 1870; died August 11th, 1903.

John Elfreth Watkins, elected Associate January 2d, 1889; died August 11th, 1903.

The Secretary announced that the Board of Direction had decided that the Annual Convention of 1904 would be held at St. Louis, Mo., during the week beginning October 3d, at which time there will also meet an International Congress of Engineering, of which this Society has been asked to take charge.

Adjourned.

September 16th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 65 members and 14 guests.

A paper entitled "Theory of Centrifugal Pumps and Fans; Analysis of Their Action, with Suggestions for Designs," by Elmo G. Harris, M. Am. Soc. C. E., was presented by the Secretary, who also read communications on the subject by Messrs. William Mayo Venable and E. T. Adams. The paper was discussed further by Messrs. Allen Hazen and W. M. White.

A second paper, entitled "Tests of the Efficiency of Hoisting Tackle," by S. P. Mitchell, M. Am. Soc. C. E., was also presented by the Secretary.

The Secretary announced the following deaths:

JOHN AUSTIN PATTERSON, elected Member May 2d, 1900; died May 3d, 1903.

REUEL WILLARD WARE, elected Member April 1st, 1874; died September 11th, 1903.

ROBERT DELANO CUSHING, elected Associate Member September 6th, 1899; died September 8th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

September 1st, 1903.—8.35 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Craven, Davison, Knap, Moore, Osborn, Osgood, Pegram, Schneider and Wilgus.

It was decided to hold the Thirty-sixth Annual Convention of the Society at St. Louis, Mo., during the week beginning October 3d, 1904.

Under a resolution of the last Annual Meeting, to the effect that the Society should co-operate with the Louisiana Purchase Exposition Company in the inauguration of an International Congress of Engineering, and the Society having been invited by the Exposition authorities to take charge of such International Congress, the following Committee to represent the Society in the matter was appointed:

Chairman, HENRY S. HAINES;	*Vice-Chairman*, L. F. G. BOUSCAREN;
WILLIAM METCALF,	BENJAMIN M. HARROD,
WILLIAM P. CRAIGHILL,	M. T. ENDICOTT,
E. L. CORTHELL,	JOSEPH RAMSEY, Jr.,
ROBERT W. HUNT,	L. B. STILLWELL,
A. A. ROBINSON,	GEORGE B. POST,
M. L. HOLMAN,	PALMER C. RICKETTS,
Treasurer, JOSEPH M. KNAP;	*Secretary*, CHAS. WARREN HUNT.

Reconsideration Ballots were canvassed and Frank Churchill Horn was declared elected a Member of the Society.

A report was received from the Committee representing the Board in the matter of the proposed Joint Engineering Building, and the following resolution was unanimously adopted:

Whereas, at the Annual Convention held at Asheville, June 10th, 1903, resolutions were passed authorizing the Board of Direction to hold conferences bearing on the advisability of the acceptance of Mr. Carnegie's proposition to this Society for a proposed Union Engineering Building, and

Whereas, at a meeting of the Joint Committee on said Building the Committee representing this Board expressed the opinion that unless an entire division of the building, fund, and management, is made between the Engineers' Club, and the four technical societies proposing to use said building, this Board cannot see its way clear to recommend to the American Society of Civil Engineers the proposition to join with the others in the project.

Resolved, that the said action of the Committee of this Board is hereby endorsed as having the approval of the Board of Direction of the Society.

The following Committee to recommend the award of prizes for the year ending with the *Transactions* of June, 1903, was appointed: Charles E. Greene, E. P. Dawley, Wynkoop Kiersted.

The report of the Nominating Committee was received.

Applications were considered and other routine business transacted.

One candidate for admission as Associate, and seven as Junior were elected.*

Adjourned.

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* See pages 342 and 343.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, October 7th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership and ballots on the proposed amendment to the Constitution will be canvassed, and a paper by Francis Robert Johnson, M. Am. Soc. C. E.; entitled "South African Irrigation," will be presented for discussion.

This paper was printed in *Proceedings* for August, 1903.

Wednesday, October 21st, 1903.—8.30 P. M.—At this meeting two papers will be presented, as follows: "Some Railway Construction in Oklahoma," by A. G. Allen, Assoc. M. Am. Soc. C. E.; and "The Fatigue of Cement Products," by J. L. Van Ornum, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for August, 1903.

Wednesday, November 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by Eugene Goetze, Esq., entitled "Filtration for Public Water Supplies, with Especial Reference to the Double Filtration Plant at Bremen, Germany," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

Wednesday, November 18th, 1903.—8.30 P. M.—At this meeting a paper by George Cecil Kenyon, Assoc. M. Am. Soc. C. E., entitled "Dock Improvements at Liverpool," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an Engineering Exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

ROBERT MOORE, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
EDWARD C. CARTER, M. Am. Soc. C. E., Chicago, Ill.
MORDECAI T. ENDICOTT, M. Am. Soc. C. E., Washington, D. C.
JAMES L. FRAZIER, " " Frankfort, Ind.
WILLIAM JACKSON, " " Boston, Mass.
EMIL KUICHLING, " " New York, N. Y.
JOHN F. WALLACE, " " Chicago, Ill.
H. J. PFEIFER, Assoc. M. Am. Soc. C. E., St. Louis, Mo., *Secretary.*

INTERNATIONAL ENGINEERING CONGRESS.

The Society has also agreed to take charge of an International Engineering Congress to be held at St. Louis during the week beginning October 3d, 1904, and has appointed the following Committee, under whose supervision this work will be carried on:

HENRY S. HAINES,	M. Am. Soc. C. E.,	New York, N. Y.,	*Chairman.*
L. F. G. BOUSCAREN,	" "	Cincinnati, O.,	*Vice-Chairman.*
WILLIAM METCALF,	" "	Pittsburg, Pa.	
BENJAMIN M. HARROD,	" "	New Orleans, La.	
WILLIAM P. CRAIGHILL,	" "	Charlestown, W. Va.	
M. T. ENDICOTT,	" "	Washington, D. C.	
E. L. CORTHELL,	" "	New York, N. Y.	
JOSEPH RAMSEY, Jr,,	" "	St. Louis, Mo.	
ROBERT W. HUNT,	" "	Chicago, Ill.	
L. B. STILLWELL,	" "	New York, N. Y.	
A. A. ROBINSON,	" "	St. Louis, Mo.	
GEORGE B. POST,	" "	New York, N. Y.	
M. L. HOLMAN,	" "	St. Louis, Mo.	
PALMER C. RICKETTS,	" "	Troy, N. Y.	
JOSEPH M. KNAP,	" "	New York, N. Y.,	*Treasurer.*
CHAS. WARREN HUNT,	" "	New York, N. Y.,	*Secretary.*

ANNUAL CONVENTION, 1904.

It has also been decided to hold the Thirty-sixth Annual Convention at St. Louis during the same week (beginning October 3d, 1904).

It is expected and hoped that the visit of members of the Institution of Civil Engineers to this country, by invitation of this Society, will be so timed that their participation in the International Engineering Congress will be assured.

As the details of the above matters are developed, they will be announced in *Proceedings.*

ACCESSIONS TO THE LIBRARY.

From August 9th to September 8th, 1903.

DONATIONS.*

TELEPHONY.

A Manual of the Design, Construction, and Operation of Telephone Exchanges. By Arthur Vaughan Abbott. Parts I–III. Cloth, 8 x 6 ins., illus. New York, McGraw Publishing Company, 1903. $1.50 per volume; set of six, $6.00.

It has been the endeavor of the author to collect in this series the consensus of what appears to be the best prevailing practice, in the hope that it may at least serve as a guide-post along the telephonic road. Part I. commences with rules for the selection of the office site. Part II. deals with the history of conduit construction. It endeavors to portray and describe the conduit forms of the present, such as experience has sanctioned. In Part III. the author has collected such data as he believes may be of service to the telephone engineer in the design and installation of the underground portion of the wire circuits, and has pointed out the principal direction which the probable trend in the design and manufacture of the cables of the future will take.

CHIMNEY DESIGN AND THEORY.

A Book for Engineers and Architects. By William Wallace Christie, M. Am. Soc. M. E. Second Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 8 + 192 pp., illus. New York, D. Van Nostrand Company, 1902. $3.00.

To this edition some twenty-five pages of text and twelve full-page illustrations have been added. Radial brick chimneys, which were just being introduced in the United States as the first edition went to press, are now treated briefly. The author has endeavored to round out the work, thus meeting some of the criticisms made by the reviewers of the original publication. The Contents are: Introduction and History; Theory of Chimney Draft; Chimney Formulæ; Chimney Tables, Wind Pressure, Air-Space in Grates; Foundation Materials, Brick Chimney Materials; Steel Chimneys—Theory Pertaining to Same, and Examples from Existing Structures; Brick Chimneys—Theory Pertaining to Same, and Examples from Existing Structures; Chimney Performances—Special Types—Straightening Chimneys—Flues; House Chimneys; Lightning Protection; General Information. There is an index of eleven pages.

STONES FOR BUILDING AND DECORATION.

By George P. Merrill. Third Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 11 + 551 pp., illus. New York, John Wiley & Sons, 1903. $5.00.

The preface states that this work is based upon the author's handbook and catalogue of the collection of building and ornamental stones in the United States National Museum at Washington. The book has been written from an American standpoint, and treats principally of stones found within the limits of the United States, or imported from other sources. In but few instances are stones mentioned that are of purely historical interest. The changes introduced in the present edition consist of much additional material, correction of errors where found, and an entire revision of the chapter on methods of testing. A brief chapter on the use of drift bowlders for building purposes has also been introduced. Some new illustrations, including five maps showing the geographic distribution of the more important stones, have been added. The Contents are: Historical; The Geographical Distribution of Building-Stones in the United States; The Minerals of Building-Stones; Physical and Chemical Properties of Building-Stones; Rock Classification; Geological Record; Igneous Rocks; Aqueous Rocks; Methods of Quarrying and Dressing Stone; Machines and Implements used in Stone-Working; The Weathering of Building-Stone; On the Selection and Testing of Building-Stone; Methods of Protection and Preservation; Appendices. There is an index of eleven pages.

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* Unless otherwise specified, books in this list have been donated by the Publishers.

THE ELASTICITY AND RESISTANCE OF THE MATERIALS OF ENGINEERING.

By Wm. H. Burr, M. Am. Soc. C. E.; M. Inst. C. E. Sixth Edition, Rewritten and Enlarged. Cloth, 9 x 6 ins., 15 + 990 + 80 pp., illus. New York, John Wiley & Sons, 1903. $7.50.

The preface states that the present edition of this work constitutes almost a new book, one-half or more of the entire volume being new matter. Much of the latter contains original matter not hitherto published. Portions of those chapters on combined bending and direct stress and on the theory and design of concrete-steel members are of this nature. The effort has been to set forth the treatment of concrete-steel beams and other members with fulness, in order to meet the requirements of that rapidly extending field of engineering construction. The author has been permitted to include in this volume a set of tables and cuts of rolled shapes taken from the Handbook of the Cambria Steel Company. The chapters are: Elementary Theory of Elasticity in Amorphous Solid Bodies; Hollow Cylinders and Spheres and Torsion; Flexure; Resilience; Combined Stress Condition; Tension; Compression; Shearing and Torsion; Bending or Flexure; Concrete-Steel Members; Rolled and Cast Flanged Beams; Connections; Plate Girders; Ropes and Chain Cables; Miscellaneous Problems; Working Stresses and Safety Factors; The Fatigue of Metals; The Flow of Solids; General Equations; Thick Hollow Cylinders and Spheres, and Torsion; Energy of Elasticity; Theory of Flexure; Another Method for Finding Pitch of Rivets. There is an index of twelve pages.

MODERN MACHINE SHOP TOOLS.

Their Construction, Operation and Manipulation, Including Both Hand and Machine Tools. By William H. Van Dervoort. Cloth, 9 x 6 ins., 552 pp., illus. New York, Norman W. Henley & Company, 1903. $4.00.

This book is an outgrowth of a series of articles prepared by the author for the students in machine-shop practice at the University of Illinois; some of these articles having been published recently in "Machinery." An effort has been made to treat the subject in a comprehensive manner, avoiding all unnecessary matter and presenting to the apprentice and mechanic many points pertaining to the tools with which they come in daily contact, and about which they are often unable to obtain all the information necessary, in order that they may use these tools correctly and efficiently. The chapter headings are: The Hammer and Cold Chisel; The File and Filing; Scrapers and Scraped Surfaces; Standards of Measure; Calipers; Gauges and Indicators; Rules, Squares and Other Small Tools; Drills; Reamers; Taps and Dies; Drill and Tap Holders; Mandrels; The Lathe; The Lathe in Modified Forms; Lathe Tools; Chucks and Drivers for Lathe Work; Lathe Work, between Centers; Lathe Work on Face Plate, Chuck and Carriage; Boring and Turning Mills; Planing and Shaping Machines, Their Tools and Attachments; Planer and Shaper Work; The Slotting Machine and Key Seater; Milling Machines; Milling Machine Cutters; Milling Machine Work; Gear Cutters and Gear Cutting; Drilling Machines and Drilling Work; Grinding Machines and Grinding; Hardening and Tempering; Fastenings; Gearings; Belting and Transmission Machinery; Miscellaneous Shop Equipment and Conveniences; Useful Tables and Data. There is an index of eight pages.

ELECTRICAL ENGINEERING.

An Elementary Text-Book Suitable for Persons Employed in the Mechanical and Electrical Engineering Trades, for Elementary Students of Electrical Engineering, and for All Who Wish to Acquire a Knowledge of the Chief Principles and Practice of the Subject. By E. Rosenberg. Translated by W. W. Haldane Gee, A. M. I. E. E., and Carl Kinzbrunner. Cloth, 9 x 6 ins., 13 + 267 pp., illus. New York, John Wiley & Sons, 1903. $1.50.

This book had its origin in a number of lectures which the author delivered to the workmen and the staff of a large electrical manufacturing firm. The circle of readers for which this book is intended is, in the first place, the same as that to which the audience belonged. It is intended to give workmen of electrical engineering works the knowledge of the operation of machines and apparatus with which they are concerned. The author has endeavored to use language which people who have only a general school education should be able to understand. In the translation, some change from the original has been inevitable in giving an English dress to the work. The illustrations have been revised, and a number from English firms have been added. The chapter headings are: Fundamental Principles; Magnets—Magnetic Lines of Force; The Continuous-Current Dynamo; The Electric Motor; Accumulators; Working of Dynamos in Parallel; Electric Lighting; Alternating Currents; Alternators; Alternating-Current Motors; Multiphase Alternating-Current; High Tension. There is an index of three pages.

CATALOGUE OF THE NATIONAL FIRE PROOFING COMPANY OF PITTSBURGH.

Abridged Edition. Author and Compiler, Henry L. Hinton. Morocco, 7 x 5 ins., unpaged, illus. New York, National Fire Roofing Company, 1903. $3.00.

This edition of the catalogue, as is stated in the preface, consists chiefly of a selection of completed pages as electrotyped for an unabridged edition of a forthcoming work in eight different divisions, four of which only are represented here, and these only in part. The following is a synopsis of the abridged edition: Side-Construction Flat Arches; End-Construction Flat Arches; Combination-Construction Flat Arches; "Lintels;" Segmental Arches; Serrated Arches; Girder-Covering Construction; Typical Methods of Construction; Condensed Safe Load Tables; Moment of Resistance Tables—for Beams; Sound-Proof Tests.

AMERICAN STREET RAILWAY INVESTMENTS.

Published annually by the *Street Railway Journal*. For the Use of Bankers, Brokers, Capitalists, Investors and Street Railway Companies. Tenth Annual Volume. 1903. McGraw Publishing Company, New York. $5.00.

The reports of the various railways of which about 1,360 are included in this work, are this year arranged alphabetically by States. There is a comparative table of the gross receipts in 1901 and 1902. The reports for each company give a brief general description of the road, its equipment, operation, traffic and financial statistics, list of officers, etc.

Gifts have also been received from the following:

Aachen Technische Hochschule. 1 pam.
Allentown, Pa.—Water Dept. 1 pam.
Am. Inst. of Arch. 1 vol.
Am. Inst. of Elec. Engrs. 1 pam.
Am. Ry. Eng. and M. of W. Assoc. 1 vol.
Am. Soc. Mech. Engrs. 1 pam.
Anthracite Coal Operators' Assoc. 1 pam.
Assoc. des Ingénieurs Sortis des Écoles Spéciales de Gand. 1 pam.
Assoc. of Railway Telegraph Supts. 1 pam.
Beveridge, A. J. 1 pam.
Boston, Mass.—Board of Gas and Elec. Light Commrs. 1 vol.
Boston, Mass.—Dept. of Parks. 1 pam.
Cal.—Board of State Harbor Commrs. 4 pam.
Canada—Dept. of Agri. 6 bound vol., 4 vol.
Canada—Dept. of Pub. Works. 17 vol.
Chicago, Ill.—Health Dept. 1 bound vol.
Chicago & North Western Ry. Co. 1 pam.
Cooper Union. 27 pam.
Denver, Colo.—State Engr. 1 bound vol.
Dingle, J. H. 1 bound vol.
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Fisk, W. L. 1 map, 1 vol., 4 pam.
Flynn, John, Jr. 2 bound vol. 1 pam.
Ga.—State Geologist. 1 bound vol.
Gila Valley, Globe & Northern Ry. Co. 1 pam.
Great Britain—Patent Office. 9 pam., 7 vol.
Hannover Technische Hochschule. 1 pam.
Harrisburg, Pa.—City Clerk. 9 vol.
Hering, Rudolph. 1 pam.
Ill.—Canal Commrs. 15 vol., 7 pam.
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Medford, Mass.—Water Commrs. 1 pam.
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Min. Soc. of Nova Scotia. 1 pam.
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Philadelphia, Pa.—Bureau of Surv. 1 bound vol.
Philadelphia, Pa.—Bureau of Water. 1 bound vol.
Philadelphia Commercial Museum. 1 pam.
Polytechnic Inst. of Brooklyn. 1 vol.
Ricketts, Palmer C. 2 vol.
St. John, N. B.—Water and Sewerage Dept. 1 pam.
Tillson, G. W. 1 vol.
Tombo, Carl. 1 vol.
U. S. Bureau of Insular Affairs. 6 vol.
U. S. Bureau of Labor. 1 pam.
U. S. Chf. of Engrs. 14 specif.
U. S. Office of Exper. Stations. 1 pam.
U. S. Weather Bureau. 1 bound vol.
Wellcome Physiological Research Laboratories. 1 bound vol.
Western Soc. of Engrs. 1 pam.
Wis.—State Geol. Surv. 4 bound vol., 1 vol., 2 pam.
Wyo.—State Engr. 2 vol.

BY PURCHASE.

Gas and Petroleum Engines. A Manual for Students and Engineers. By William Robinson, M. Inst. C. E., M. Inst. M. E., M. Inst. E. E. Second Edition, Completely Rewritten. London, E. & F. N. Spon, Ltd.; New York, Spon & Chamberlain, 1902.

The Metallurgy of Zinc and Cadmium. By Walter Renton Ingalls. *Engineering and Mining Journal*, New York, London, 1903.

Modern Electrolytic Copper Refining. By Titus Ulke. New York, John Wiley and Sons; London, Chapman & Hall, Limited, 1903.

The Hydro-Metallurgy of Copper, Being An Account of Processes Adopted in the Hydro-Metallurgical Treatment of Cupriferous Ores, Including the Manufacture of Copper Vitriol . . . with Chapters on the Sources of Supply of Copper and Roasting of Copper Ores. By M. Eissler. London, Crosby Lockwood and Son, 1902.

Ore-Deposits. A Discussion Re-Published from the *Engineering and Mining Journal.* New York, May, 1903. New York and London, *The Engineering and Mining Journal*, 1903.

The Louisiana Purchase and Our Title West of the Rocky Mountains, with a Review of Annexation by the United States. By Binger Hermann. Washington, Government Printing Office, 1900.

The Michigan Engineer, Containing the Proceedings of the Michigan Engineering Society, 1902–03. 2 vol. Published by the Society, Climax, Mich., 1902–03.

The American Woods, Exhibited by Actual Specimens and with Copious Explanatory Text. By Romeyn B. Hough. Parts I–IX. Lowville, N. Y., Published and Sections Prepared by the Author, 1892–1903.

Repertorium der technischen Journal-Literatur. Herausgegeben im kaiserlichen Patentamt. 1902. Berlin, Carl Heymann, 1903.

Railway Legislation in the United States. By Balthasar Henry Meyer. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1903.

American Street Railway Investments. A Supplement to the *Street Railway Journal.* Published Annually for the Use of Bankers, Brokers, Capitalists, Investors, and Street Railway Companies; 1894–1902. 9 vol. New York, Street Railway Publishing Company, 1894–1902.

Colonial and Camp Sanitation. By George Vivian Poore. Longmans, Green and Co., London, New York and Bombay, 1903.

Building Superintendence. A Manual for Young Architects, Students and Others Interested in Building Operations as Carried on at the Present Day. By T. M. Clark. New Edition, Revised and

Rewritten. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1903.

A Treatise on Hydraulics. By Henry T. Bovey. Second Edition, Rewritten. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1902.

SUMMARY OF ACCESSIONS.

August 9th to September 8th, 1903.

Donations (including 13 duplicates)	255
By Purchase	23
Total	278

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
HAYES, GEORGE SAMUEL. 111 Fifth Ave., New York City	Jun.	Dec. 6, 1892
	Assoc. M.	June 3, 1896
	M.	Sept. 2, 1903
METCALF, LEONARD. Cons. Engr., 14 Beacon St., Boston, Mass.	Assoc. M.	Jan. 5, 1898
	M.	Sept. 2, 1903
MOGENSEN, OLAF EINAR. Chf. Engr.'s Office, Mo. Pac. Ry. Co., St. L., I. M. & S. Ry. Co., and Leased, Operated and Independent Lines, 502 Missouri Pacific Bldg., St. Louis, Mo.	Assoc. M.	April 7, 1897
	M.	Sept. 2, 1903
ROPES, HORACE. Engr., Weston Aqueduct Dept., Met. Water and Sewerage Board, Mass., South Framingham, Mass.		Sept. 2, 1903
SERJEANT, HUGH. Care, Western Australian Ry. Dept., Office of Chf. Engr., Perth, Western Australia		Dec. 4, 1901
TUCKEY, THOMAS WILLIAM TOWNSEND. Dist. Engr., Imperial Rys. of North China, Tangku, North China		June 3, 1903

ASSOCIATE MEMBERS.

KELLEY, JAMES AUGUSTUS. Engr. for T. H. Clement & Co., Contrs., 32 South Broad St., Philadelphia, Pa.	Assoc.	Mar. 5, 1901
	Assoc M.	Sept. 2, 1903
LEWIS, CLIFFORD, Jr. Second National Bank Bldg., Utica, N. Y.		Sept. 2, 1903
MAXIMOFF, SERGIUS PAVLOVITCH. Engr. to the Imperial Russian Govt.; Asst. at the Imperial Inst. of Public Ways at St. Petersburg, Zabalkanski pr. 67, St. Petersburg, Russia		April 1, 1903
MURPHY, JOSEPH EDGAR. Div. Engr., Galesburg and St. Louis Divs., C., B. & Q. R. R., Room 7½ C., B. & Q. Depot, Galesburg, Ill.		Sept. 2, 1903
TIDD, ARTHUR WARREN. Care, Comm. on Additional Water Supply, Room 2105, Park Row Bldg., New York City.		June 3, 1903
VON UNWERTH, HANS. Asst. Engr., Waddell & Hedrick, 608 New Nelson Bldg., Kansas City, Mo.		May 6, 1903

ASSOCIATES.

TOCH, MAXIMILIAN. Toch Bros., 468 West Broadway, New City.		Sept. 1, 1903

JUNIORS.

PILLET, FREDERICK FISCHER. Asst. Engr., Board of Public Works, City Hall, Mobile, Ala.		June 2, 1903
SAUER, ALFRED FRANCIS. 1158 East Jersey St., Elizabeth, N. J.		Sept. 1, 1903
SMALL, JAMES HAMPDEN, Jr. 129 West 83d St., New York City.		Mar. 31, 1903

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TAYLOR, HARRY.....Capt., Corps of Engrs., U. S. A., Company L, Battalion of Engrs., Manila, Philippine Islands.

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FOX, WALTER GORDON.....Bulls Bridge, Conn.

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SHIMA, TAKEJIRO.....Bei Frau Büwendt, Goethestr., 13/I, Charlottenburg, Berlin, Germany.

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BELZNER, THEODORE.....Insp., Steel Constr., Manhattan Valley Viaduct, Rapid Transit R. R. Comm., 231 West 125th St. (Res., 584 Lenox Ave.), New York City.

CLASS, CHARLES FRANK.....Asst. Engr., Am. Coke & Gas Constr. Co., Camden, N. J.

DAVIS, GEORGE JACOB, Jr.....Care, N. B. Livermore, Rialto Bldg., San Francisco, Cal.

GOULD, JOHN WARREN DU BOIS.....Smith Creek Hotel, Mt. Hamilton, Cal.

GRAY, JOHN COLIN.....Care, Bureau of Highways, Room 19, Municipal Bldg. (Res., 17 Lenox Rd.), Brooklyn, N. Y.

HARRIS, HENRY ALEXANDER.....Asst. Engr., Ferrocarril Central de Guatemala, Guatemala.
HYATT, CALEB.....Room 32, Union Station, Albany, N. Y.
KIMBALL, RALPH CHARLES.....Box 45, Owensville, Clermont Co., Ohio.
McHARG, LESLIE.....159 Madison Ave., New York City.
MERZ, LEON.....1730 Memorial Ave., Philadelphia, Pa.
MINER, JAMES HENRY.....Engr., Page Coal & Coke Co., Elkhorn, W. Va.
WILGUS, HERBERT SEDGWICK.....Prin. Asst. Engr., Brooklyn Heights R. R. Co., 168 Montague St., Brooklyn, N. Y.

FELLOWS.

GREEN, SAMUEL MAGEE.....R. R. Contr., 740 Wells Bldg., Milwaukee, Wis.

DEATHS.

ABERT, SYLVANUS THAYER.....Elected Member September 21st, 1870; died August 11th, 1903.
PALMER, CORNELIUS.....Elected Member November 2d, 1887; died July 31st, 1903.
WARE, REUEL WILLARD.....Elected Member April 1st, 1874; died September 10th, 1903.
WATKINS, JOHN ELFRETH.....Elected Associate January 2d, 1889; died August 11th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(Aug. 9th to Sept. 8th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis aes École Spéciales de Gand*, Brusseis, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

Bridge.

Erection of the Nairne Viaducts, near Adelaide, South Australia. Walter Edmund Cook, M. Inst. C. E. (63) Vol. clii.
Early and Curious Types of the Cantilever Bridge in New England and New Brunswick.* Alfred W. Parker. (Paper read before the Boston Soc. of Civ. Engrs.) (1) July.
Cantilever Bridge at Connel Ferry.* (11) July 31.
The New Manhattan Bridge. (12) Aug. 14.
The Wabash Bridge at Pittsburg.* (15) Aug. 14.
The Specifications for the Superstructure of the Blackwell's Island Bridge.* (14) Aug. 22.
The Blackwell's Island Bridge.* (15) Aug. 28.
The Superstructure for the Blackwell's Island Bridge Across the East River at New York City.* (13) Sept. 3.
Repairing the Williamsburg Bridge Cables.* (14) Sept. 5.
Erection of the Atlantic Avenue Improvement Viaduct, Brooklyn.* (14) Sept. 5.
Note sur le Calcul Graphique des Ponts en Arc à Triple Articulation par la Méthode des Lignes d'Influence.* M. Jacquier. (43) 1er Trimestre.
Mémoire sur la Reconstruction du Pont de Frans.* G. Canat. (43) 1er Trimestre.

Electrical.

The Cauvery Power-Transmission Scheme. Harold Thornthwaite Hincks, Assoc. M. Inst. C. E. (63) Vol. clii.
Electric Automobiles.* Henry Francis Joel, Assoc. M. Inst. C. E. (63) Vol. clii.
The Experimental Basis for the Theory of the Regulation of Alternators.* B. A. Behrend. (42) June.
A Study of the Heyland Machine as Motor and Generator.* Comfort A. Adams. (42) June.
The Compounding of Self-Excited Alternating Current Generators for Variation in Load and Power Factor.* A. S. Garfield. (42) June.
A Discussion of Some Points in Alternating Current Theory.* W. S. Franklin. (42) June.
Some Features of Telephone Traffic and Their Effect on Service. J. G. Wray. (42) June.
Properties of Wire Used in Telephone Work. R. A. L. Snyder. (58) June.
Electric Rock Drills. E. J. Munby. (8) July.
Hot Wire Enclosed Arc Lamps.* H. Tomlinson-Lee. (26) July 31.
The Possibilities of Future Economies in Electrical Illumination. W. A. Chamen. (Paper read before the Incorporated Municipal Elec. Assoc.) (47) Aug. 1.
The Necessity for Precision of Statement in Technical Work. H. M. Hobart. (26) Serial beginning Aug. 7.
Development of Electric Station Power Plant. Elihu Thomson. (Abstract of Paper read before the National Elec. Light Assoc.) (47) Aug 8.
Notes on a Subaqueous Electric Power Cable.* (13) Aug. 13.
A Mexican Water-Power Electric Plant.* (13) Aug. 13.
Tests on Broken Cables—Some Inconsistencies in Localization Formulæ. E. Raymond-Barker. (26) Serial beginning Aug. 14.
Wimbledon Electricity Works.* (26) Aug. 14.
A Combined Railway, Lighting and Ice Plant at Hampton, Va.* (14) Aug. 15.
The Electric Installation on Board U. S. Battleships *Connecticut* and *Louisiana*.* R. M. Klein. (27) Aug. 15.
The Electrical Plant in the Newark Free Public Library.* (27) Aug. 15.
Electric Conduit Construction at Cincinnati, O.* (13) Aug. 20.
Hydro-Electric Works at La Praz.* (12) Aug. 21.
Tangential Traction. (26) Serial beginning Aug. 21.
Necessary Practical Safeguards against Fires Caused by Lightning. Alfred Hands. (Abstract of Paper read before the International Fire Prevention Congress.) (26) Aug. 21.
The New Cuban Telegraphic Service.* Chas. Minor Blackford, Jr. (19) Aug. 22.
The New Denver Telephone Exchange of the Colorado Telephone Company.* C. W. Whitney. (27) Aug. 22.
Leblanc Rectifying Transformer.* (27) Aug. 22.
Electrical Plant Failures: Their Origin and Prevention. A. Campbell Cormack. (Abstract of Paper read before the Inst. of Min. Engrs.) (47) Aug. 22; (13) Sept. 3.
Electricity in the Shop—Speed Regulation of Motors.* H. M. Phillips. (62) Serial beginning Aug. 27.
The Water Power Plant of the Columbia Mills Company, Columbia, S. C.* (14) Aug. 29.
Compound Wound *vs.* Shunt Converters. P. M. Lincoln. (17) Aug. 29.
Possible Economies in Central Station and Distribution Systems. Philip Dawson. (17) Aug. 29.
The Transmission of a 23 000-Volt Direct Current over a Distance of Thirty-five Miles.* Emile Guarini. (19) Aug. 29.
The Nernst Incandescent Lamp.* (19) Aug. 29.
The Earth as a Condenser and Its Role in Wireless Telegraphy. (27) Aug. 29.
Feeder Calculations for Direct Current Railways. (27) Aug. 29.

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Electrical—(Continued).

Some Tests of Recording Wattmeters. Ingwald A. Rosok. (27) Aug. 22; (24) Aug. 31.
Great Electric Installations of Italy: The Rome-Tivoli Power Plant and Transmission.* Enrico Bignami. (9) Sept.
Aluminium Conductors for Electric Transmission Lines. Alton D. Adams. (9) Sept.
Power Plant of the Pittsburg, McKeesport & Connellsville Railway.* (14) Sept. 5.
Rouleau Compresseur-Corroyeur Électrique: Système P. Sarrazin. (35) Aug.
État Actuel du Labourage Électrique.* Émile Guarini. (33) Aug. 22.

Marine.

Dry Dock at Riley's Hill on the Richmond River, New South Wales.* Alexander Donald Craig, Assoc. M. Inst. C E (63) Vol. ciii.
A Steam Lifeboat.* (11) Aug. 14
American Vessels, Naval and Mercantile. (12) Aug. 14.
The New Floating Dock for Durban.* (12) Aug. 14.
The Modern Racing Yacht an Engineering Proposition.* W. P. Stephens. (9) Sept.
Application des Moteurs à Pétrole à la Navigation.* A. Bochet. (32) June.
Le Paquebot à Turbines *The Queen* du Service Calais-Douvres.* A. Dumas. (33) Aug. 1.

Mechanical.

The Riedler Pump.* H. D. D. Barman. (59) Vol. xxv, Pt. 4.
Stuffing-Boxes Dispensed with on Engines and Pumps. Andrew Watson. (59) Vol. xxv, Pt. 4.
Steel Forgings. T. D. Lynch. (58) June.
Some Characteristics of Good Forgings and Some Things to Avoid. James H. Baker. (58) June.
Drop Forging. Dwight Goddard. (58) June.
Cold Rolled Steel. J. J. Crane. (58) June.
Power Plant Design. R. W. Stovel. (58) June.
The Burning of Pulverized Coal. C. O. Bartlett. (Paper read before the Civ. Engineers' Club of Cleveland.) (1) July.
A New Form of Friction Clutch.* H. S. Hele-Shaw. (Paper read before the Inst. of Mech. Engrs.) (11) July 31; (47) Serial beginning Aug. 8; (Abstract) (26) Aug. 21; (Abstract) (57) Aug. 21.
The New Plant at the Duquesne Works of the Carnegie Company.* (22) July 31.
The Diesel Engine.* H. Ade Clark. (Paper read before the Inst. of Mech. Engrs.) (11) Serial beginning July 31; (47) Serial beginning Aug. 1.
Coal and Coke Handling Plant at the Dunfermline Gas-Works. Alexander Waddell. (Paper read before the North British Assoc. of Gas Managers.) (66) Aug. 4.
Remarks upon the Principles Involved in the Production of Gases from Coal, and Suggestions as to Their Application in Future Developments. William Young. (Paper read before the North British Assoc. of Gas Managers.) (66) Aug. 4.
Experiments on the Efficiency of Non-Conducting Coverings for Steam-Piping.* W. N. Bolam and T. Grieve. (11) Aug. 7.
The Musker Steam Motor Wagon.* (11) Aug. 7.
Economy of Fuel in Electric Generating Stations. Henry McLaren. (Paper read before the Inst. of Mech. Engrs.) (11) Aug. 7; (12) Aug. 7; (47) Aug. 15.
Theory of the Alcohol Motor. C. C. Longridge, M. I. Mech. E. (12) Aug. 7.
Compound Road Locomotive.* (12) Aug. 7.
Electrically Driven Compressors for Drills, Coal-Cutters and Hauling Machinery.* (22) Aug. 7.
The Gas Engine and Its Future. (26) Serial beginning Aug. 7.
The Valuation of Gas Coals. (24) Aug. 10.
Springs. Wm. Metcalf. (Paper read before the Amer. Soc. for Testing Materials.) (62) Serial beginning Aug. 13; (Abstract) (47) Aug. 8.
High Pressure Gas Distribution. John A. Britton. (Paper read before the Pacific Coast Gas Assoc.) (24) Aug 17.
Wrought Pipe. Franklin Riffle. (Paper read before the Pacific Coast Gas Assoc.) (24) Aug. 17.
The Molding Machine.* S. H. Stupakoff. (Paper read before the Amer. Foundrymen's Assoc.) (20) Aug. 13.
Chimney Draft. D. B. Dixon. (62) Aug. 13.
Exhaust Steam Turbines.* (62) Aug 13.
The Cruse Controllable Superheater.* (11) Aug. 14.
Boring and Turning Mill for Electric Generators.* (11) Aug. 14.
Mechanical Features in the Use of Superheated Steam. (40) Aug. 14.
A Concrete Measuring, Feeding and Mixing Plant.* (14) Aug. 15.
A Combined Railway, Lighting and Ice Plant at Hampton, Va.* (14) Aug. 15.
The Manufacture and Utilization of Mond Producer Gas for Industrial Purposes.* (19) Aug. 15.
Manufacture and Employment of Gas from Heavy Oil in Germany. (From the German of M. W. Scheihauer, in the *Journal für Gasbeleuchtung.*) (19) Aug. 15.
A Combined Exhaust Valve and Igniter for Gasoline Motors.* (19) Aug. 15.

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Mechanical—(Continued).

Extensions at the Evesham Gas-Works; Purifiers without Connections.* R. J. Milbourne, Assoc. M. Inst. C. E. (66) Aug. 18.
Gaseous Firing at the Waterford Gas-Works.* R. Bruce Anderson, Assoc. M. Inst. C. E. (Paper read before the Irish Assoc. of Gas Managers.) (66). Aug. 18.
Laying a High Pressure Gas Main Across the Mississippi River at New Orleans.* Thomas D. Miller. (Abstract of paper read before the Western Gas Assoc.) (13) Aug. 20.
Boiler and Furnace Efficiencies.* A. Bement. (Abstract of Paper read before the National Electric Light Assoc.) (20) Aug. 20.
The Power Required to Drive Centrifugal Machines.* (11) Aug. 21.
Malleable Cast Iron. R. Moldenke. (Paper read before the Amer. Foundrymen's Assoc.) (12) Aug. 21.
Specifications for Beehive Coke Ovens.* (22) Aug. 21.
The West Allis Plant of the Allis-Chalmers Company.* (14) Serial beginning Aug. 22.
The Briquette Industry in France. Ed. Loze. (16) Serial beginning Aug. 22.
The K. & G. Cube Concrete Mixers.* (18) Aug. 22.
Metallic Packings.* Charles Longstreth. (From *Journal* of the Amer. Soc. of Naval Engrs.) (47) Aug. 22.
Test of Engine Using Kerosene and Gasolene.* H. F. Halladay and G. O. Hodge. (47) Serial beginning Aug. 22.
Liquid Air: Its Manufacture, Distillation into Commercial Oxygen and Nitrogen, and the Application of Oxygen in the Industries, Especially for Use in Connection with Illuminating Gas. G. A. Bobrick. (Paper read before the Pacific Coast Gas Assoc.) (24) Aug. 24.
Vertical Gas-Retorts in America.* (66) Aug. 25.
Loss of Illuminating Power of Mantles While Burning. A. H. White and M. E. Mueller. (Paper read before the Michigan Gas Assoc.) (66) Aug. 25.
Compressed Air for Raising Water from Deep Wells and Borings. W. H. Maxwell, Assoc. M. Inst. C. E. (From paper read before the British Assoc. of Water-Works Engrs.) (66) Aug. 25.
The Efficiency of Concrete Mixing Machines.* Clarence Coleman, M. Am. Soc. C. E. (13) Aug. 27.
The Pittsburgh Fuel Saving Device.* (20) Aug. 27.
Drop Forging. Dwight Goddard. (Paper read before the Engineers' Soc. of Pennsylvania.) (20) Aug. 27.
An English Measuring Machine.* (20) Aug. 27.
Notes on High Speed Tool Steels. Henry H. Suplee. (62) Aug. 27.
A New Spiral Elevator.* (14) Aug. 29.
Automatic Paper-Feeders for Printing Machinery.* (46) Aug. 29.
The Large Gas Engine in Great Britain: Blast Furnace Gas As a Factor in Its Development.* William H. Booth. (10) Sept.
Collapses of Furnace Crowns; a Suggested Explanation.* H. M. Rounthwaite. (10) Sept.
Machine Tools for Engine Building.* George T. Reiss. (10) Sept.
Motor-Driven Machine Tools—Recent Practice in the Application of Electric Drives to Drilling Machinery.* (25) Sept.
Boiler Corrosion—What Corrosion Is—Different Causes and Various Means by Which It May be Remedied or Prevented. (45) Sept.
Stamp Cams and Cam-Shafts: A Description of the Different Forms of Cams and Methods of Fastening them to the Shaft.* (45) Sept.
Analyses and Fuel Value of the Pittsburg Coal in the Fairmount Region of West Virginia. Frank Haas. (45) Sept.
Portland Cement Manufacture: Preparation of Dry Materials for the Kiln. Edwin C. Eckel. (60) Sept.
A 6 000 Horse-Power Conover Jet Condenser.* (64) Sept.
The E. Keeler Company Water Tube Boiler.* (64) Sept.
Theory of Stiff and Flexible Shafts and Critical Speeds.* Sanford A. Moss. (64) Sept.
Measuring the Horse-Power of Steam Engines.* E. C. Oliver. (64) Sept.
Gas Engines at the Dusseldorf Exposition.* R. Mathot. (64) Sept.
The Use of Reheaters in Compound Engines.* George H. Barrus. (Abstract of Paper presented to the New England Cotton Mfrs. Assoc.) (64) Sept.
The Inland Steel Company's Indiana Harbor Works.* (20) Sept. 3.
A German Reversing Valve for Regenerative Furnaces.* (20) Sept. 3.
Etudes sur la Circulation de l'Eau dans les Chaudières à Vapeur.* A. Montupet. (32) June.
Le Broyeur à Vilebrequins Cléro.* A. de Gennes. (32) July.
Vérins Pneumatiques pour le Levage des Fardeaux.* (34) Aug.
Distribution de Vapeur.* (34) Serial beginning Aug.
L'Incandescence par le Gaz. Ch. Féry. (33) Aug. 8.
Le Ballon *Zeppelin*.* G. Espitallier. (33) Aug. 8.
Fabrication Mécanique de Bouteilles.* H. Aurive. (36) Aug. 10.
Nouveaux Types de Surchauffeurs de Vapeur.* (33) Aug. 15.
Lucrerie de Ketzin, Pres de Berlin.* (33) Aug. 22.
Lampes pour Appareils de Projection à Incandescence par l'Alcool.* A. Veroy. (36) Aug. 25.

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Metallurgical.

The Light Aluminum Alloys. Joseph W. Richards. (Paper read before the Amer. Soc. for Testing Materials.) (20) Aug. 13.

The Influence of Varying Casting Temperature on the Properties of Alloys.* Percy Longmuir. (Paper read before the Iron and Steel Inst.) (11) Serial beginning Aug. 14.

The Detection of the Finishing Temperatures of Steel Rails by the Thermo-Magnetic Selector.* Albert Sauveur and Jasper Whiting. (15) Aug. 14.

The Manufacture and Properties of Nickel-Steel. Albert Ladd Colby, M. Am. Soc. M. E. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 20; (14) Serial beginning Aug. 22; (20) Aug. 20; (15) Aug. 14.

Pipeless Ingots of the Sauveur Method.* Albert Sauveur and Jasper Whiting. (Paper read before the Amer. Soc. for Testing Materials.) (62) Aug. 20; (47) Aug. 8; (15) Aug. 14.

The Desulphurization of Slimes by Heap Roasting at Broken Hill. E. J. Horwood. (Abstract from *Transactions* of the Australasian Inst. of Min. Engrs.) (16) Aug. 22.

Volatilization of Metals as Chlorides. Stuart Croasdale. (16) Aug. 29.

Cyanidation at the Kalgurli Mine, Kalgoorlie.* Edwin O. Watt. (Abstract from *Transactions* of the Australasian Inst. of Min Engrs.) (16) Aug. 29.

The Metallography of Iron and Steel.* Henry M. Howe. (9) Sept.

Roasting and Filter-Press Treatment at Kalgoorlie. J. T. Marriner. (16) Sept. 5.

The Extraction of Gold from Cyanide Slimes by a Wet Method. John Fleming. (16) Sept. 5.

Electro-Métallurgie du Zinc.* A. Salgués. (32) July.

Exposé des Derniers Expériences Industrielles Électro-Métallurgiques pour la Fonte de Minerais de Cuivre dans des Fours Électriques Réalisées en France. Ch. Vattier. (32) July.

Essais Récents de Plaques Cémentées (1902-1903). L. Baclé. (33) Aug. 15.

Recherches sur les Aciers au Manganese.* Léon Guillet. (33) Serial beginning Aug. 22.

Military.

The Richards Prismatic Stadia as a Range-Finder. E. K. Landis. (2) July.

The Military Importance of Naval Engineering Experiments. George W. Melville. (2) July.

The Topham Rifle Mechanism.* (12) July 31.

Military Graphics. Charles W. Larned. (44) Sept.-Oct.

Mining.

Underground Fires. F. W. Hardwick, A. M. I. C. E. (Paper read before the British Fire Prevention Cong.) (57) July 31.

New Methods of Filling in the Goaf in Germany.* (From Report of Prussian Comm. on the Fall of Stone and Coal in Mines.) (22) Aug. 7; Aug. 21.

Acetylene Lamps in German Collieries.* (22) Aug. 14.

Improved Appliances, &c., Introduced into German Mines in 1902.* (From *Zeitschrift für Berg-, Hütten-, und Salinenwesen.*) (57) Serial beginning Aug. 14.

Gold Mining and Milling in Ecuador.* J. W. Mercer. (16) Aug. 15.

Belt Elevators. (16) Aug. 15.

Electric Power Appliances in the Mines of Europe.* Emile Guarini. (9) Sept.

Electric Coal-Mining Plants. S. B. Belden. (45) Sept.

Traversing Winding Engine for Deep Shafts.* H. M. Morgans. (Paper read before the Inst. of Min. and Metallurgy.) (45) Sept.

Fatal Accidents in Coal Mines in North America, 1902. Frederick L. Hoffman. (16) Sept. 5.

The Santa Eulalia Ore Deposits.* Philip Argall. (16) Sept. 5.

L'Embouage Comme Méthode de Remblayage.* H. Schmerber. (33) Aug. 8.

Miscellaneous.

A Century's Progress in Engineering Education in the United States. Robert Heywood Fernald. (Paper read before the Engineers' Club of St. Louis.) (1) July.

Mechanical Drawing in the Modern Drafting Room.* George H. Follows. (58) July.

Drawing Room Practice for Manufacturing Companies. J. L. Klindworth. (58) July.

System in an Engineering Office. W. E. Fohl. (58) July.

Instruments de Mesure de Haute Précision pour les Ateliers Mécaniques.* A. Galassini. (37) July 31.

Municipal.

Notes upon Municipal Work in Sydney, New South Wales. Richard Watkins Richards, M. Inst. C. E. (63) Vol. cliii.

Recent Developments of the Asphalt Industry. William Henry Delano, Assoc. Inst. C. E. (63) Vol. cliii.

The Use of Motor Vehicles for Municipal Purposes in England. (13) Aug. 13.

Fire Patrol Service for Dock Property: Fire Preventive Methods at the Docks of the Manchester Ship Canal.* W. H. Hunter, M. Inst. C. E. (Paper read before the International Fire-Prevention Cong.) (11) Aug. 21.

Use of Mineral Oil in Road Improvement. James W. Abbott. (13) Aug. 27.

Experiments on the Value of the Absorption Test for Paving Brick.* (60) Sept.

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Railroads.

The Construction of the Lu-Pao District of the Lu-Han Railway.* Thomas Johnstone Bourne, Assoc. M. Inst. C. E. (63) Vol. clii.
Reduction of Grade on Railroads.* C. D. Purdon. (Paper read before the Engineers' Club of St. Louis.) (1) July.
Bogie Express Engines, Class D: South Eastern and Chatham Railway.* (21) Aug.
Interurban Railway Development in Great Britain. Robert P. Porter. (17) Serial beginning Aug. 8.
Back Bay Station, Boston; New York, New Haven & Hartford Railroad.* (18) Aug. 8.
The Construction of the Simplon Tunnel.* (13) Serial beginning Aug. 13.
The Southern Pacific Shops at East Los Angeles.* (15) Aug. 14.
Grade Reduction on the Illinois Central.* (15) Aug. 14.
The Renovo Shops—Pennsylvania Railroad.* (40) Aug. 14.
Injectors on the Backhead of Locomotive Boilers.* (40) Aug. 14.
Plans of the Holland Sleeping Car.* (17) Aug. 15.
All-Metal Box Cars on Mexican Railway.* (18) Aug. 15.
Drawbar and Buffer Attachments for Use between Engine and Tender. (18) Aug. 15.
Electric Locomotives on French Railways.* (19) Aug. 15.
Shops of the Locomotive & Machine Company of Montreal.* (15) Aug. 21.
Heavy Electric Locomotive for the B. & O.* (15) Aug. 21; (17) Aug. 22; (27) Aug. 22; (40) Aug. 21.
German Locomotive Designs for High Speed Service.* Lawford H. Fry. (15) Aug. 21.
The Life of Treated Ties.* (15) Aug. 21.
The New Rock Island Shops at East Moline, Ill.* (40) Aug. 21.
The New Baltimore & Ohio Electric Locomotive.* (14) Aug. 22.
New General Shops of Chicago & Eastern Illinois Ry.* (18) Aug. 22.
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Sectional Electric Locomotives for the Baltimore Tunnel of the Baltimore & Ohio Ry.* (13) Aug. 27.
The Inspection of Rails. C. W. Gennet, Jr. (15) Aug. 28.
The Illinois Central Improvements—New Lines and Second Track.* (15) Aug. 28.
The Care of Locomotive Boilers. M. E. Wells. (Abstract of Paper presented to the Pacific Coast Ry. Club.) (15) Aug. 28.
Northern Pacific Consolidation Locomotive.* (40) Aug. 28.
Concrete Roundhouse and Freight Depot.* (40) Aug. 28.
Central Railroad of New Jersey Composite Box Car.* (40) Aug. 28.
The Moll Switch Rod and Adjustable Clamp.* (40) Aug. 28.
The Utica & Mohawk Valley Railway.* (17) Aug. 29.
Fonda, Johnstown and Gloversville System.* (17) Aug. 29.
The Albany and Hudson Third-Rail System. (17) Aug. 29.
The Tools and Methods of a Swiss Locomotive Works.* Charles R. King. (9) Sept.
The Railway Town of Crewe: The Home of the London & North-Western Railway Works.* Charles S. Lake. (10) Serial beginning Sept.
Compound Locomotive with Superheater: 4-6-0 Type, Freight: Canadian Pacific Railway.* (25) Sept.
New Locomotive Shops at Topeka—Atchison, Topeka & Santa Fé Railway.* (25) Serial beginning Sept.
The Sheedy Circulating Pipe for Locomotive Cylinders.* (25) Sept.
Revoluble Car-Dumping Structure.* Erskine Ramsay. (45) Sept.
Steel Cars of the Side-Door Type for Suburban Traffic; Illinois Central R. R.* (13) Sept. 3; (15) Sept. 4.
Power Plant of the Pittsburg, McKeesport & Connellsville Railway.* (14) Sept. 5.
Erection of the Atlantic Avenue Improvement Viaduct, Brooklyn.* (14) Sept. 5.
Des Gares de Raccordement entre Chemins de Fer & Voies Navigables sur les Canaux de Roanne à Digoin Latéral à la Loire et du Nivernais.* M. Mazoyer. (43) 1er Trimestre.
Emploi d'Enclenchements Provisoires dans les Grandes Gares Pendant les Périodes de Détèlement des Cabines à l'Occasion de Travaux d'Agrandissement ou de Remaniement d'Installations Existantes: Dispositions de Réseaux Funiculaires pour Réaliser les Enclenchements Provisoires en Cabine.* M. Moutier et M. Sabourin. (38) Aug.
Étude sur la Statistique des Avaries et Ruptures d'Essieux du Matériel des Chemins de Fer de l'Union Allemande. E. Biard. (38) Aug.
Station Centrale d'Énergie Électrique de Batavia, États-Unis.* (Aurora, Elgin & Chicago Ry.) (33) Aug. 1.
Locomotives Compound à Trois Cylindres de la Compagnie du Midland.* R. Bonnin. (33) Aug. 8.
Applications de l'Électricité aux Chemins de Fer.* B. Lorcy. (36) Serial beginning Aug. 10.
Éclairage des Voitures de Chemins de Fer au Moyen de l'Incandescence par le Gaz.* (33) Aug. 22.
Automotrice à Vapeur de la Compagnie du Chemin de Fer du London and South Western.* R. Bonnin. (36) Aug. 25.

Railroad, Street.

Notes on the Construction of the Permanent Way of Electric Tramways.* Robert Bruce, Stud. Inst. C. E. (63) Vol. clii.
Lowestoft Municipal Electrical Tramways.* (26) Aug. 7.

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Carriage of Merchandise on Electric Tramways. Thomas Upton. (26) Serial beginning Aug. 14.
Motor Trucks for the New York Subways.* (17) Aug. 15.
Electric Tramways of Sydney (N. S. W.) Extensions.* (26) Aug. 21.
Section Nine of Division Three of the New York Rapid Transit Railroad.* (14) Serial beginning Aug. 22.
Details of Construction of the Paris Underground Railway beneath the Place de l'Opera.* (19) Aug. 22.
The Interurban System of the South Lancashire Tramways.* (17) Aug. 22.
Cars for the New York Subway.* (17) Aug. 22.
London's "Tubes"—The Novel Method of Their Construction.* (19) Aug. 22.
High-Acceleration on Electric Railways: Results on the Liverpool Overhead Line. Herbert C. Fyfe. (19) Aug. 22.
Modern Repair Shop Methods.* Richard McCulloch. (17) Aug. 29.
The Hudson Valley Railway.* (17) Aug. 29.
United Traction System of Albany.* (17) Aug. 29.
Schenectady's City, Suburban and Interurban Electric Railway Facilities.* (17) Aug. 29.
Power Equipment for City Roads.* (17) Aug. 29.
Standard Practice in City Track Construction.* (17) Aug. 29.
Standard Overhead Construction in City Streets.* (17) Aug. 29.
Standard Practice in Rolling Stock for City Service.* (17) Aug. 29.
Electric Traction in Sydney, New South Wales.* Arthur C. F. Webb, M. I. E. E. (27) Aug. 29.
Schuckert Surface-Contact Street Railway System.* S. N. Taylor. (27) Aug. 29.
The Metropolitan Underground Railway of Paris: Construction of the North Circle.* (13) Sept. 3.
Report of the New York Rapid Transit Commissioners.* (15) Sept. 4.
Matériel Roulant du Manhattan Railway.* Henry Martin. (33) Aug. 1.

Sanitary.

The High-Level Sewer of the Metropolitan Sewerage District of Massachusetts.* John S. Hodgson. (14) Serial beginning Aug. 15.
Street Cleaning in San Francisco. L. M. King. (From a paper in the *Merchants' Association Review.*) (13) Aug. 20.
On the Distribution of Sewage on Bacteria Beds. John C. Thresh and Martin Priest. (Paper read before the Sanitary Inst.) (11) Aug. 21.
Sewage Pumping Plant.* (12) Aug. 21.
Heating and Ventilating the Shops and Offices of the Pennsylvania Steel Company.* (40) Aug. 21.
Infiltration of Ground Water Into Sewers. J. N. Hazlehurst, M. Am. Soc. C. E. (13) Aug. 27.
Cleaning a Large Brick Sewer in Hartford, Conn. Frederick L. Ford, Assoc. M. Am. Soc. C. E. (From *Bulletin* of the Connecticut Soc. of Civ. Engrs.) (13) Aug. 27.
A Large Concrete-Steel Sewer (Cleveland).* (14) Aug. 29.
La Nouvelle Usine d'Incinération des Immondices de la Ville de Bruxelles: Note. J. Leurs. (30) Aug.
Les Avantages et les Inconvénients des Égouts du Système Unitaire et du Système Separatif. (33) Aug. 15.

Structural.

Recent Developments of the Asphalt Industry. William Henry Delano, Assoc. Inst. C. E. (63) Vol. clii.
Nickel Steel for Purposes of Construction. Ralph H. Watson. (58) June.
Protective Coatings for Iron and Steel. (Report of Committee of Amer. Soc. for Testing Materials.) (40) Aug. 14.
Soundness Tests of Portland Cement.* (Abstract of Paper by W. P. Taylor before Amer. Soc. for Testing Materials and of discussion by Robert W. Lesley.) (14) Aug. 15.
Manufactured Marble. (19) Aug. 15.
Standard Test Bars for Cast Iron. Alex. E. Outerbridge, Jr. (Paper read before the Amer. Soc. for Testing Materials.) (47) Aug. 15.
The Manufacture and Properties of Nickel-Steel. Albert Ladd Colby, M. Am. Soc. M. E. (Abstract of Paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 20; (14) Serial beginning Aug. 22; (20) Aug. 20; (15) Aug. 14.
The Works of the Lackawanna Steel Company.* (22) Aug. 21.
The Practical Protection of Metal Surfaces in Gas Plants. L. P. Lowe. (Paper read before the Pacific Coast Gas Assoc.) (24) Aug. 24.
The Manufacture and Properties of Hydrate of Lime. S. Y. Brigham. (13) Aug. 27.
The Efficiency of Concrete Mixing Machines.* Clarence Coleman, M. Am. Soc. C. E. (13) Aug. 27.
Auxiliary Pneumatic Caisson Work for the Bank of the State of New York.* (14) Aug. 29.
Concrete House Building.* (46) Aug. 29.
The Uses of Concrete in Recent Engineering Practice. Samuel H. Lea, M. Am. Soc. C. E. (Paper read before the Scranton Engineers' Club.) (45) Sept.

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The Influence of Variations in Water and Sand on Cement. E. S. Larned. (Paper read before the Amer. Soc. for Testing Materials.) (14) Sept. 5.
A New System of Seasoning Wood with Saccharine or Sugar. (10) Sept. 5.
La Métallographie Microscopique et Son Utilisation Comme Méthode d'Essais.* Léon Guillet. (32) July.

Topographical.

The Richards Prismatic Stadia as a Range-Finder. E. K. Landis. (2) July.
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FILTRATION FOR PUBLIC WATER SUPPLIES, WITH ESPECIAL REFERENCE TO THE DOUBLE FILTRATION PLANT AT BREMEN, GERMANY.

By Eugen Goetze, Esq.*

To be Presented November 4th, 1903.

The present rules of the German Imperial Board of Health regarding sand filtration comprise a number of important results concerning the building and operation of sand-filter works. They are based upon the experience of many years, collected from the reports of twenty-six filter works. These rules have been printed in full in leading technical publications of the several countries of Europe, and also in America, and reference is made to some of them, in connection with this description of some of the characteristic features of the Bremen filter-works.

The filtration of surface-water is satisfactory when the filtrate is clear, and, as regards color, taste, temperature and chemical composition, is not worse than before filtration, and does not contain more than about 100 bacteria per cubic centimeter, when tested according to a

* Chief Engineer of the Water-Works in Bremen.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

prescribed procedure, including cultivation at 20° Cent. for 48 hours. The bacteriological examination should be made by a permanent officer of the works. The possible pathogenic quality of the bacteria found in the filtrate is not brought into question by this bacterial examination, but the method is merely a means for a delicate discrimination between the results of filtration, and affords a very good control of the operation of the filters. It is based upon the fact that after long experience any filtrate which does not contain the usual low number of bacteria must be viewed with suspicion, or as being of an inferior quality. The figure 100 is merely an approximate limit of the number of bacteria found in satisfactory filtrates of German filters.

The bacteriological examination of every filter should be made daily if possible. If this is not practicable, then daily observations should be made, in accordance with the standard method, at least at the following times: First, for at least two days after starting a filter that has been cleaned, and until the result is satisfactory. Second, after the loss of head due to frictional resistance in the sand layer is more than two-thirds of the allowable maximum. Third, when the head suddenly decreases. Fourth, when high (turbid) water is encountered.

Turbidity observations of the raw water, and, when necessary, of the filtrate, should be taken. They are quite valuable, because, as against the bacteriological observations, they give immediate results, and because the increase of turbidity and the increase of bacteria run parallel. The observation tube, in the apparatus used for this purpose in Bremen, has a length of about 100 cm. Clear water has a transparency greater than this length. Turbid water allows the mark or index to be seen, perhaps, through only 2 to 3 cm. A turbid filtrate, which sometimes results from single filters at high water, shows the index at 40 to 50 cm.

In order to record the degree of clearness to be indicated by this apparatus, samples of water were compared with a series of standards in which clear water is made turbid artificially by adding a known weight of the slimy matter or mud scraped from the surface of dirty filters, after eliminating those portions of it which subside quickly. This gave the results shown in Table No. 1.

Concerning the preparation of the turbidity standards, it is to be remembered that parts per million correspond to milligrams per liter,

hence the figures in the second column of Table No. 1 show the number of milligrams of mud added to one liter of water.

TABLE No. 1.

COMPOSITION OF TURBIDITY STANDARDS CORRESPONDING TO VARIOUS DEGREES OF CLEARNESS OF WATER.

Degree of clearness.	Parts of mud per million of water.
More than 100.	Perfectly clear water.
100	1.7
90	2.2
80	2.8
70	3.7
60	4.8
50	6.5
40	9
30	13
20	22
10	44
5	100

The number of bacteria in the raw water of the Weser, which normally is about 1 000 to 2 000 per cubic centimeter, but often is only a few hundreds, increases at high water, such as occurs regularly once or twice in the fall and once or twice in the spring, up to 100 000 per cubic centimeter.

As a preparation of river waters for filtering, preliminary sedimentation in settling basins, operated either intermittently or continuously, may be used with success. The result is equally good in both cases. Smaller settling basins are required for continuous than for intermittent operation. Frost has no deciding influence upon the operation of open settling basins.

It is not generally admissible to reduce the otherwise necessary area of filters on account of the introduction of settling basins. Therefore, the cost, due to the interest on the investment for the settling basins, often exceeds the expected advantage, and it will be more useful to spend the capital saved by the omission of these basins to increase the area of the filters and apply a slower rate of filtration.

In filters which are carefully provided with a sand layer of even grain, and through which the flow of water is regulated according to the best means known to the art, a process of cleaning takes place analogous to that which in Nature produces the highly praised spring water, and justly praised, if, in its formation, it passes through a natural earth filter of sufficient uniformity of material and of sufficient capacity.

If sand filtration is ever justly blamed on account of imperfect operation, the explanation is to be found in errors originating from insufficient knowledge of the nature of filtration. The filtering medium, in the basin filled with sand, is not the sand *per se*, but the slimy coating (*Schlammdecke*) which is deposited upon and between the grains of the upper layer of sand.

The favorable interaction of bacteria and algæ, the organisms consuming and producing oxygen, should also be mentioned. The bacteria are parts of the slimy coating which are most effective for the filtration. Their work must be done in the uppermost layer, and requires, in the first place, a slow filter velocity. Filtration, for the most part, then, is accomplished in the upper portion of the sand layers, from 20 to 30 mm. in thickness, and the lower layers are thus a safeguard.

In Bremen, and in most cities of Germany, 100 mm. per hour is assumed as the limit of filter velocity; but this rate is reached only during the few days of maximum delivery, when the reserve filters are out of service on account of cleaning. In Hamburg the filter areas have been computed for a maximum velocity of 63 mm. per hour.

If only the uppermost portion of the sand layer is used as a biological filter, decreasing in intensity in a downward direction, and assuming a slow filtering velocity, then there is the guaranty that any bacteria escaping through the upper layers will still be retained in the lower layers.

The foregoing process in a filter for drinking-water, because it is in the main a biological one, has not an unlimited effectiveness respecting the number of bacteria removed. Based on innumerable observations, it is necessary to assume that a ripe filter, provided with a "schlammdecke," can completely free a raw water of a certain quantity of bacteria and turbidity. In order to get an approximate idea as to what is meant by a certain quantity of bacteria, it will be assumed that there are 10 000 per cubic centimeter in the raw water. The result is a filtrate with a fairly low and constant number of bacteria. If the raw water contains a much greater number of bacteria than mentioned above, the number in the filtrate is no longer constant, but rises and falls in proportion to the number in the raw water. The essentially different behavior of the filter, whether receiving good or moderately good raw water on the one hand or bad raw water on the other hand, must be carefully distinguished.

This fact is presented most clearly by marking on a diagram, as ordinates, the numbers of bacteria in the raw water and in the filtrate. It is then readily seen that, as long as the raw water has not a very large number of bacteria, the bacteria curve of the filtrate is practically parallel with the zero line, and does not follow the irregularities of the raw-water bacteria curve. After observing this fact for many years, one becomes convinced that, within the above-mentioned limits, the number of bacteria in the filtrate stands in no relation to the number in the raw water. While the bacteria in the raw water have been completely removed, those in the filtrate have entered it subsequently and accidentally.

A filter bed filled with clean sand is not an apparatus which could be called a filter, in the sense of drinking-water purification. Only by the so-called "schlammdecke" is there formed the filter which is suitable to retain the bacteria and the often still smaller particles of clay. This improved faculty of retention, inherent to a filter that has been in use for some time, is called "ripeness."

From what has been said, the slimy coating originating during filtration must be guarded from destruction with all care. Therefore, interruptions in operation and sudden changes in the filter velocity must be avoided. The increasing accumulation of slime and mud makes it necessary, however, to clean the filter after due time, that is, it is necessary to remove any coating which will not readily pass the water. In doing this, after the water of the filter has been drawn off to a level which is indispensably necessary for cleaning, only the uppermost and visibly the most dirty layer, ranging in thickness from 10 to 20 mm., and sometimes even more, is removed. After the removal of this layer the sand is smoothed down, the filter is supplied from below with filtrate until this well covers the sand, and then raw water is again admitted from above. The filter is not aerated longer than the time required for the process of cleaning.

After such a cleaning the quantitative capacity of the filter is indeed recovered, but the qualitative work, because it depends upon the existence of the slimy coating, is lessened or entirely destroyed. The more care is given to such cleaning the less will be reduction of the effectiveness of the filter relative to quality, because the biological filter, formed by the process of filtration, usually extends to a greater depth of sand, although with decreasing intensity, than that which is

removed. The coherence of the bacterial mass beneath the removed layer must not be disturbed. It is expedient, therefore, that the men stepping upon the sand be provided with wooden shoes having broad and perfectly flat soles. The removal of sand at cleanings is continued until the remaining depth approaches the allowable minimum, which, for reasons of security, is taken at 400 mm., although the biological filter does not extend as deep. Then the filter is refilled, up to its maximum thickness, with the sand, which, in the meantime, has been washed.

As the biological filter has been impaired by cleaning, and entirely obliterated by refilling, it is necessary to view the first filtrate after these proceedings as being of inferior quality and suspicious. The proof thereof is given by the bacterial examinations, and is, indeed, less distinct after a cleaning than after a refilling, because after the former some ability for proper filtration has remained. The filtrate from a new filter, from one that has been refilled, and from one that has been cleaned or scraped, should remain separated from the water delivered into the supply until the baterial examinations show favorable results, but at least 48 hours, should a previous observation of the special conditions allow this time thus to be shortened. The latter refers especially to scrapings. The worst water does not appear immediately after starting the filters, but about 24 hours later, according to what may be the first velocity of filtration, because the filter still contains in its lower layers some of the good water of the previous period, and because it was refilled with filtered water from below.

A new or refilled filter, or even a ripe filter, may deliver a poor filtrate during floods.

In order to avoid a filtrate that is suspicious or of inferior quality, two ways are possible; local conditions should decide the preference. One way is to allow the filtered water to run to waste. This may be the right way if the raw water flows upon the filters by gravity, and, during all seasons, is in sufficient quantity to permit this waste of a material percentage of the supply. The other way is to filter the suspicious filtrate a second time; that is, to allow it to enter as raw water upon another ripe filter. To do this is never an error, and in many cases it is such an advantage that it almost appears to be a necessity; for instance, when the raw water must be pumped to the filters, or when the available quantity of water is limited and requires saving.

By the second filtration the cost of pumping is saved, but would be lost if the pumped water had to be wasted subsequently. There is a further saving in cost, because the filtrate, which has already passed through a filter once, even though the water does not conform to the highest hygienic requirements, has been deprived of the coarser impurities, so that the second filter receives only a small portion of the impurities which clog the sand layer. It is more economical, therefore, to refilter this water than to purify the same quantity of raw water.

Whether or not double filtration is used, special attention should be paid in every case to the regulating apparatus. Automatic regulation is the best. These devices of the Bremen Water-Works have been gradually improved, and in their present form have been tested for years. Fig. 1, Plate XLVI, shows the balanced valve and other features appertaining to the regulation of the raw water as it flows to the Bremen filters. Fig. 2, Plate XLVI, shows the devices for the automatic regulation of the flow of filtered water, which may be described briefly as follows:

In the well into which the filtrate flows is a bent tube, the horizontal arm of which leads to the clear-water reservoir, and in the vertical arm of which, bent upward, is a bronze pipe suspended by floats working telescopically. The filtered water flows into the bronze pipe over an adjustable weir. The depth of water flowing over this weir is constant during oscillations of the water surface, but the overflow edge of the bronze pipe rises and falls with the floats. With this arrangement water flows out of the regulating chamber independently of the absolute height of water in it, but its quantity corresponds to the adjusted height of the weir. It follows that the difference between the surface of the raw water and that in the regulating chamber (in other words, the filter head) will always adjust itself to the necessary quantity. When the filter head is too great, more water flows into the regulating chamber than out of it, and the floats rise. When the head is too small, less water flows into the chamber, and the floats fall until the true head has been obtained automatically. When the surface of the raw water in the filter rises or falls, the water surface in the chamber changes correspondingly. The pressure head, therefore, remains constant, and is independent of oscillations of the raw-water surface. As the clogging of the filter, and therefore the resistance in

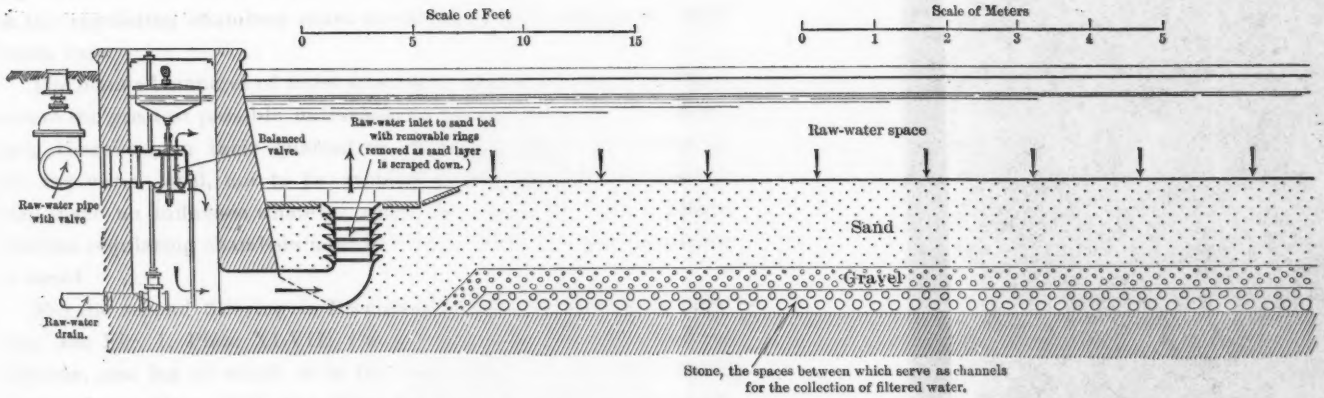


FIG. 1. PIPING CONNECTIONS AND REGULATOR FOR THE APPLICATION OF RAW WATER TO OPEN FILTERS AT BREMEN—INLET.

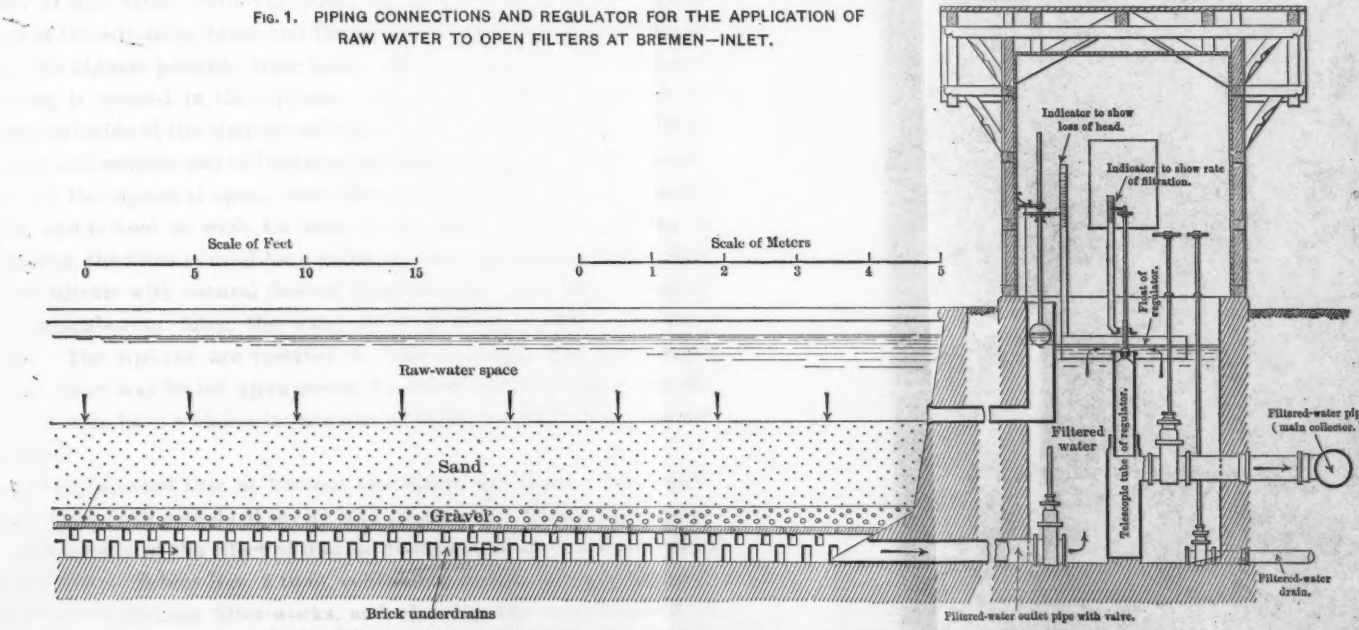


FIG. 2. OUTLET PIPING, GATE-HOUSE, AUTOMATIC TELESCOPIC REGULATOR, AND INDICATORS FOR CONTROL OF FILTERED WATER FROM OPEN FILTERS AT BREMEN.

the same, increases, the pressure head rises uniformly. Both this head and the filter velocity may be read from scales in the regulating chamber. In order to prevent injurious friction, the apparatus in the regulating chambers must be designed and constructed with much care.

The main advantages of these automatic regulators are: That they secure the greatest possible uniformity in the operation of the filters, and, therefore, in their qualitative efficiency; that oscillations in the raw-water level, not to be avoided in the operation of the filters, have no influence whatever upon the regulation of the filters; that the regulating chambers need be visited but rarely; and that labor is saved.

For the second filtering in Bremen, according to the writer's system (see Fig. 1, Plate XLVII), the several filters are connected by siphons, one leg of which is in the regulating well for the effluent water of one filter, while the other leg is in the raw-water compartment of the adjoining filter, and the top or head of the siphon is higher than the highest possible water level. By means of a water ejector, a vacuum is created in the siphons. An air-valve makes it possible to unite the inside of the siphons with the outside air, and therefore offers an easy and reliable way of breaking the siphonic action. When the air-valve of the siphon is open, every filter connected with it is a single filter, and is used as such for most of the year. After a refilling or cleansing, the filter is used for a short time as a preliminary filter, that is, the filtrate with natural descent flows into the raw-water chamber of a neighboring filter, the water level of which is kept somewhat lower. The siphons are inserted in such a manner that the filtrate of one filter may be led upon one or the other of the neighboring filters, so as to have a choice in case one of them is out of service or not yet ripe.

It will be noted that at Bremen the filters are open. For conditions where long periods of severe cold prevail, they should be covered.

Illustrative of the effect of double filtration, there is given a series of five tables (Tables Nos. 2 to 6), containing results actually accomplished at the Bremen filter-works, and showing the improvement of the filtered water resulting from the second filtration at times when ordinary operations are more or less interfered with by frost in open filters, and when the filters are scraped during periods of high and

turbid water in the river. The more essential details, descriptive of the actual conditions under which the data were obtained, are given for each of the tables.

Following the tables are deductions based on general experience at Bremen.

TABLE No. 2.

INFLUENCE OF DOUBLE FILTRATION UPON BACTERIAL EFFICIENCY, WITH A HIGH RATE FOR THE FINAL FILTER, WHEN OPEN FILTERS ARE AFFECTED BY FROST.

Date.	Bacteria per Cubic Centimeter.			
	Raw water.	Effluent of preliminary filters.		Effluent of final filter.
		Filter No. V.	Filter No. IV.	Filter No. III.
1895.				
February 26	650	920	68	23
27	950	1 000	144	8
28	775	280	90	25
March 1	1 500	1 440	70	60
2	925	540	Scraped.	Scraped.
4	1 875	276	73	46
5	2 825	280	114	50
6	3 700	470	240	55
7	2 050	230	176	67
8	3 000	186	196	63
9	2 550	174	224	46
10	2 300	136	134	34
11	1 800	73	84	45
12	2 800	52	86	36
13	6 000	62	82	42
14	11 300	76	110	29
15	12 500	74	150	31
16	8 200	70	126	32
17	.....	76	114	53
18	7 650	46	86	30
19	8 900	46	54	31
20	7 100	50	56	29
21	7 600	49	16	16
22	16 900	48	62	21
23	18 200	40	80	20
24	12 200	28	79	21
25	14 600	46	330	30
26	13 400	61	256	28

Regarding Table No. 2, it is to be stated that the "vor-filters," Nos. V and IV, are preliminary filters, through which the water was passed first, and their combined area of filtering surface was 2 320 sq. m., the thickness of the sand layer being from 850 to 950 mm. Filter No. III, through which the water was filtered the second time,

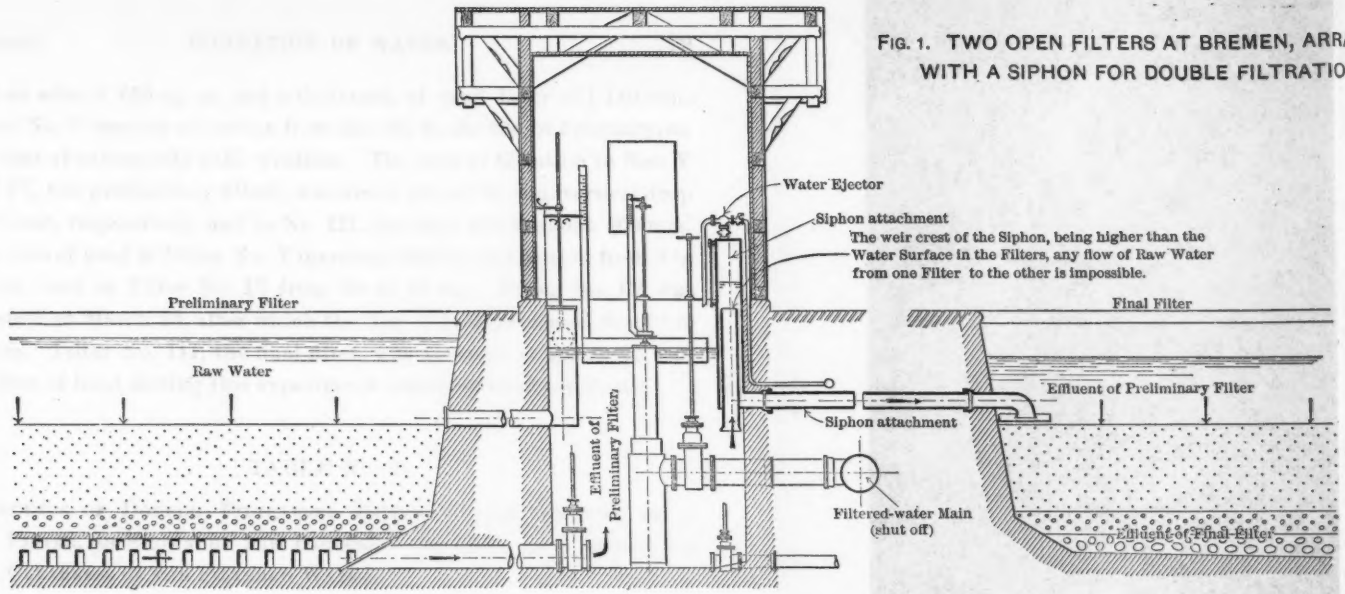


FIG. 1. TWO OPEN FILTERS AT BREMEN, ARRANGED WITH A SIPHON FOR DOUBLE FILTRATION.

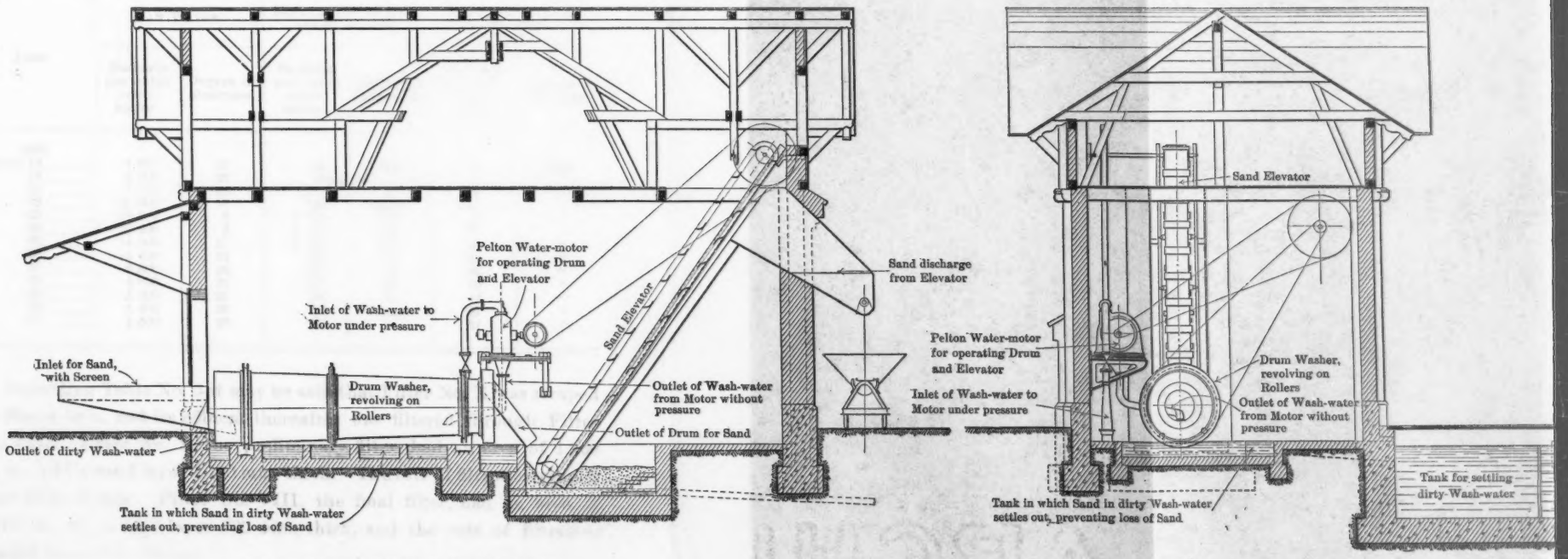


FIG. 2. SAND WASHER AT BREMEN.
DRUM AND ELEVATOR OPERATED BY WASH-WATER.

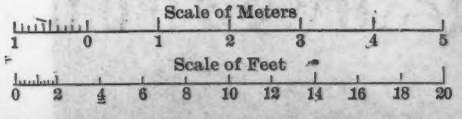
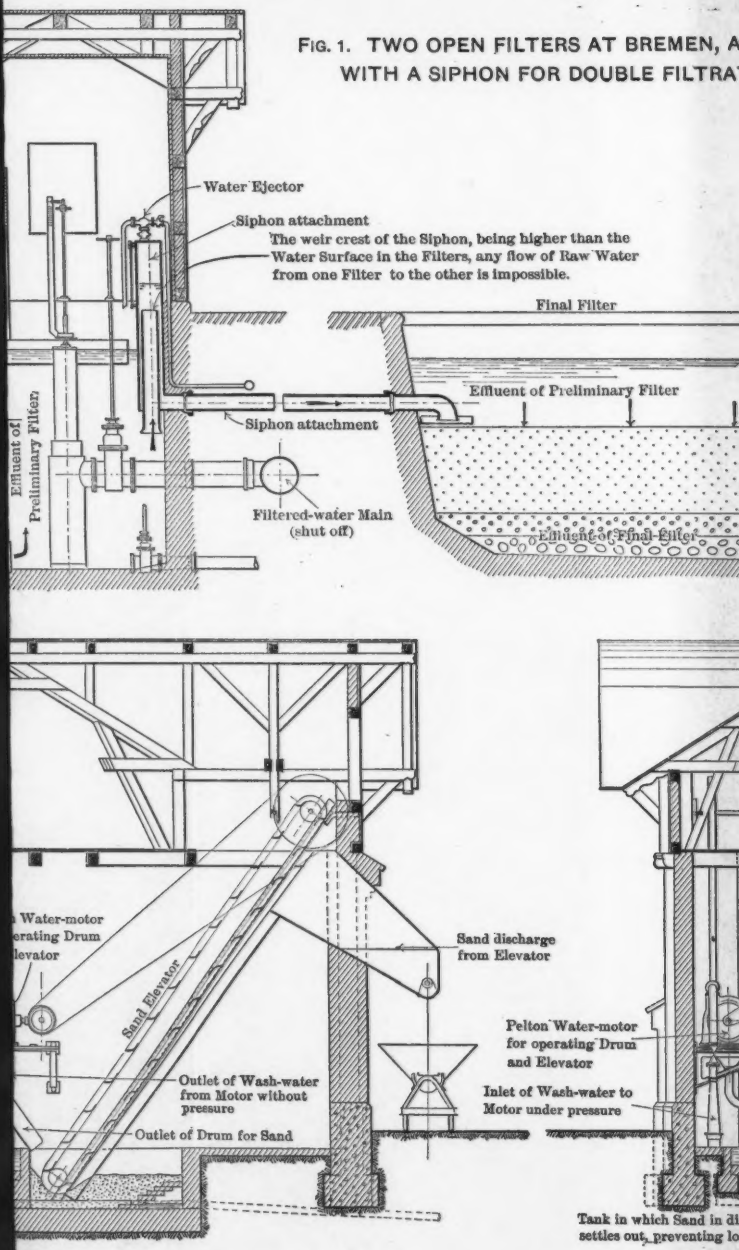


FIG. 1. TWO OPEN FILTERS AT BREMEN, A
WITH A SIPHON FOR DOUBLE FILTRA



MEN.
VASH-WATER.

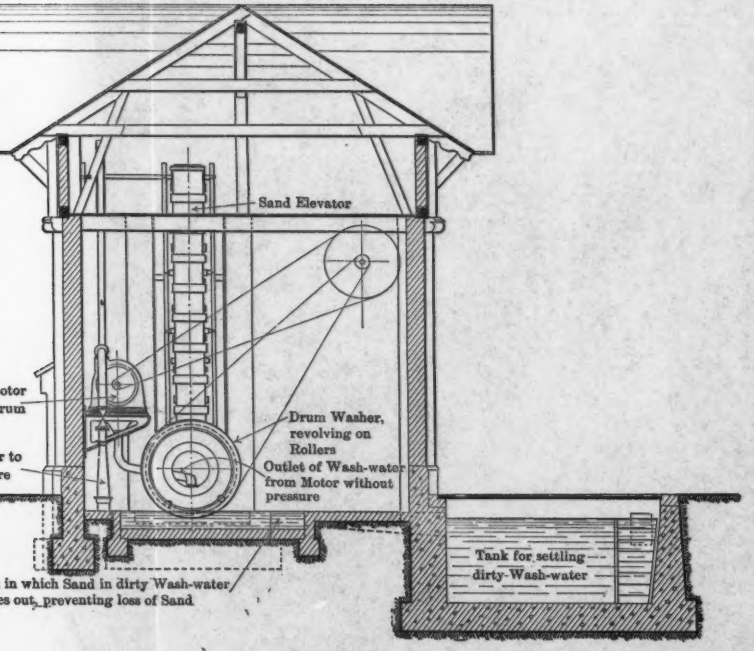
Scale of Meters
1 0 1 2 3 4 5
Scale of Feet
0 2 4 6 8 10 12 14 16 18 20

' BREMEN, ARRANGED
BLE FILTRATION.

he
ater

ary Filter

Final Filter



4 5

18 20

had an area of 650 sq. m. and a thickness of sand layer of 1 140 mm. Filter No. V was out of service from the 8th to the 23d of February, on account of excessively cold weather. The rate of filtration in Nos. V and IV, the preliminary filters, was about 60 and 50 mm. vertical drop per hour, respectively, and in No. III, the final filter, about 200 mm. The loss of head in Filter No. V increased during this period from 3 to 50 cm., and in Filter No. IV from 50 to 65 cm. Filter No. IV was scraped on March 2d, after which the loss of head increased from 7 to 52 cm. Filter No. III, the final filter, was scraped on March 3d, and the loss of head during this experiment remained at about 35 cm.

TABLE No. 3.

INFLUENCE OF DOUBLE FILTRATION FOLLOWING THE SCRAPING OF A FILTER, AS SHOWN BY THE BACTERIAL CONTENTS AND DEGREE OF CLEARNESS OF THE FILTERED WATER.

Date.	RAW WATER.		EFFLUENT OF PRELIMINARY FILTER.		EFFLUENT OF FINAL FILTER.	
	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.
1895.						
March 18.....	7 650	41	36	Clear.	21	Clear.
19.....	8 900	32	Scraped.		17	"
20.....	7 100	40	....	....	24	"
22.....	16 900	17	590	Clear.	24	"
23.....	18 200	8	1 720	72	50	"
24.....	12 200	8	1 450	85	71	"
25.....	14 600	11	1 120	91	90	"
26.....	13 400	11	790	81	64	"
27.....	9 800	19	480	87	63	"
28.....	4 600	21	210	95	70	"
29.....	5 300	21	130	95	44	"
30.....	3 400	26	92	Clear.	57	"
31.....	4 500	26	82	"	51	"

Regarding Table No. 3 it may be said that Filter No. X was scraped on March 19th, and its effluent thereafter was filtered through Filter No. VIII. Filter No. X, the preliminary filter, had an area of 1 160 sq. m., and a sand layer 1 130 mm. thick. The rate of filtration ranged from 65 to 80 mm. Filter No. VIII, the final filter, had an area of 1 310 sq. m., a sand layer 700 mm. thick, and the rate of filtration ranged from 60 to 70 mm.

Each of the two filters used in securing the data recorded in Table No. 4 had an area of 650 sq. m.

TABLE No. 4.

INFLUENCE OF DOUBLE FILTRATION AT A TIME OF HIGH AND TURBID WATER, AS SHOWN BY THE BACTERIAL CONTENTS AND DEGREE OF CLEARNESS OF THE FILTERED WATER.

Date.	RAW WATER.		EFFLUENT OF PRELIMINARY FILTER.		EFFLUENT OF FINAL FILTER.	
	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.
1896.						
March 2.....	950	53	80	Clear.	25	Clear.
5.....	2 400	56	150	"	76	"
The filters were reversed as to double filtration, that is, the effluent of Filter No. II was turned on Filter No. I (above the sand), instead of into the clear-water reservoir, and the raw water was shut off the latter.						
March 9.....	19 500	3	116	Clear.	36	Clear.
10.....	23 100	3½	295	74	17	"
11.....	28 100	5	780	61	31	"
12.....	16 900	6	616	60	60	"
13.....	19 500	7	610	63	55	"
14.....	10 100	9	620	65	34	"
15.....	11 300	14	185	70	22	"
16.....	9 000	16	155	87	48	"
17.....	4 200	22	95	95	24	"
18.....	4 600	28	76	Clear.	24	"
20.....	1 650	40	38	"	20	"
22.....	1 400	48	49	"	23	"
Double filtration was discontinued, the effluent of Filter No. II flowing to the filtered-water basin instead of to the water space above the sand in Filter No. I; raw water was applied to Filter No. I. These changes were made without any interruption in filtration, in the case of either filter.						
March 23.....	1 000	62	32	Clear.	28	Clear.
24.....	1 000	58	49	"	38	"
25.....	740	57	77	"	49	"
26.....	680	60	80	"	23	"

With the filters used in connection with Table No. 5, Filters Nos. XI and XII, the preliminary filters, had a combined area of 2 320 sq. m., and Filter No. IX, the final filter, an area of 1 600 sq. m. The rate of filtration in the preliminary filters ranged from 90 to 100 mm., and, in the final filter, from 135 to 150 mm. The loss of head in Filter No. XII increased from 4 to 24 cm., and in Filter No. XI from 3 to 25 cm. In Filter No. IX, the final filter, it was about 30 cm. when secondary filtration was undertaken by it, and this head did not increase during the experiment.

TABLE No. 5.

INFLUENCE OF DOUBLE FILTRATION AT A TIME OF HIGH AND TURBID WATER, AS SHOWN BY THE BACTERIAL CONTENTS AND DEGREE OF CLEARNESS OF THE FILTERED WATER.

(Two Preliminary Filters and one Final Filter.)

Date.	Raw Water.		Effluent of Preliminary Filter.		Effluent of Preliminary Filter.		Effluent of Final Filter.	
	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.	Bacteria per cubic centimeter.	Degree of clearness.
1896.								
March 2.....	950	53	Scraped.		46	Clear.	12	Clear.
5.....	24 000	56	110	Clear.	160	"	..	"
The filters were reversed as to double filtration.								
9.....	19 500	3	270	58	290	85	56	Clear.
10.....	23 100	3½	660	39	2 840	35	223	97
11.....	28 100	5	860	52	905	50	98	Clear.
12.....	16 900	6	416	53	616	52	84	87
13.....	19 500	7	770	50	670	49	92	95
14.....	10 100	9	290	58	260	63	48	94
15.....	11 300	14	245	72	245	76	52	Clear.
16.....	9 000	16	175	75	220	83	39	"
17.....	4 200	22	90	80	190	94	44	"
18.....	4 600	28	84	Clear.	184	Clear.	25	"
19.....	2 250	32	44	"	106	"	54	"
20.....	1 650	40	48	"	50	"	18	"
22.....	1 400	48	138	"	100	"	28	"
24.....	1 000	58	42	"	61	"	8	"
Second filtration is interrupted								
25.....	740	57	36	Clear.	13	Clear.	29	Clear.
26.....	680	60	33	"	51	"	24	"

With regard to Table No. 6, it is to be stated that, while the water in the river at this period was high, no turbidity was present in the effluent of either the preliminary or final filters. Filter No. VI, the preliminary filter, had an area of 1 160 sq. m. and a thickness of sand layer of 1 120 mm. The sand itself was of fine and even grain, so that the surface of the layer could be made very smooth. Filter No. VII, the final filter, had an area of 1 160 sq. m., and a thickness of sand layer of 485 mm. The sand was of coarse and less even grain, so that the surface was less smooth than in the case of the other filter; consequently, the preliminary filter, with its finer sand, had a thicker "schlammdecke" than the final one. It will be noted that the preliminary filter worked badly on two occasions, due to cleaning, and also on

two occasions, due to high water, namely, for the several days beginning December 5th and beginning December 17th.

TABLE No. 6.

Influence of Double Filtration at High Water and after Scraping, as Shown by the Bacterial Contents of the Effluents.

Date.	Bacteria per Cubic Centimeter.		
	Raw water.	Effluent of Preliminary Filters.	Effluent of Final Filter.
		Filter No. VI.	Filter No. VII.
1897.			
November 18	2 800	Scraped.	17
19	2 300	55	9
20	1 750	700	8
21	2 025	230	10
22	1 005	68	5
23	1 325	45	9
24	875	20	6
25	1 080	30	3
26	1 100	22	11
27	950	23	4
29	2 000	75	..
December 1	4 500	94	10
2	9 600	96	9
3	29 000	105	2
4	39 200	130	10
5	38 300	525	15
6	35 600	385	32
7	17 200	165	35
8	7 600	100	30
9	6 400	75	13
10	7 000	75	23
11	7 400	70	21
12	6 400	Scraped.	6
13	10 400	290	24
14	8 000	115	12
15	10 100	115	17
16	9 600	70	20
17	11 100	135	21
18	9 300	240	37
19	6 500	105	29
20	6 600	134	31
22	.....	54	46
27	3 720	49	32
29	2 600	27	21

Referring to the data of Table No. 6, it is to be pointed out that if the effect of filtration rested only upon a mechanical process, then those bacteria which passed through the thicker "schlammdecke" and through much finer sand would also have gone through the coarser final filter. That this was not the case is surely an irrefut-

able proof that, not the depth of sand or the size of the grains, but the biological process, caused the final effect.

The fact noticed in Bremen on every occasion, that double filtration removes the fine clay which had passed the first filter, and is recognizable by an opalescent turbidity, is extremely important. It is well known that in such cases a complete clarification without filtration and without chemical means is impossible. It is also known that in bad cases simple filtration fails. Raw water, which, for instance, was so turbid that the mark on the measuring apparatus could be seen only at a distance of from 2 to 3 cm., and which with single filtration could be seen for about 50 cm., and was opalescent, was improved by double filtration, so that the mark could be seen at a distance of 100 cm., the greatest length of the apparatus, corresponding to perfectly clear water.

Double filtration gives another very instructive example, and shows that under normal conditions the bacteria from the effluent of a ripe filter are altogether independent of the number contained in the raw water, where the filtrate of the preliminary filter is the raw water of the final filter. A perfectly satisfactory filter was used as a final filter for one that had likewise been used for some time. The raw water for the preliminary filter contained on an average about 3 000 bacteria per cubic centimeter, and was changed into a filtrate containing about 40 bacteria per cubic centimeter. The filtrate, therefore, contained about 1.33% of those contained in the raw water. It was then filtered a second time, at a very uniform speed for about 10 days, and contained about 60 to 70 bacteria per cubic centimeter. The second filtrate therefore contained 150 to 175% of those contained in the water delivered by the preliminary filter. Accordingly, the filtrate from the double filter would be worse than that from the single filter, while, in fact, the water filtered twice could only be better. It seems hardly possible to have a clearer proof than this that a constant low number of bacteria, and not a percentage of reduction, should be used as a demonstration of the effective work of a filter.

On the other hand, in considering the operation of a filter with extraordinarily bad water, containing many bacteria and being very turbid, it is found that a constant number of bacteria for the filtrate can no longer be counted upon. In the long, flat curve representing the number of bacteria in the filtrate, there is a very perceptible

irregular movement, a rise and fall analogous to the rising and falling of the bacteria in the raw-water curves. Here the number of bacteria in the filtrate can be expressed temporarily by a percentage of the number contained in the raw water.

No filtrate which is characterized by a noticeable irregularity in the otherwise fairly horizontal bacteria curve should be permitted in the water supply, but should be considered as suspicious water and filtered a second time.

A very noticeable phenomenon accompanying the high number of bacteria contained in the filtrates from flood water, and a very impressive sign of its inferior quality, is the slight turbidity, *i. e.*, the opalescence of the filtrate obtained from very turbid yellow river water. It is not difficult to separate such an imperfect filtrate from the other water intended for distribution, if the cause for such an imperfect filtrate is known, which is generally the case. In general, these periods of opalescent water are noticed after the cleaning of a filter, after refilling it with clean sand, and when the raw water is worse than normal. During these three different periods we should make use of a possibility, hitherto little used, to enable the single filters of a large plant mutually to support each other, in filtering once more the filtrate obtained after single filtration, in case it is not perfect.

It is important, as will be recognized at once, from what has been stated, that the filter which is used as the final filter should have a "schlammdecke," for otherwise it is not a filter, in our sense. And water having received a preliminary filtration contains only a few of those elements which produce a "schlammdecke," and is therefore unsuitable to transform a bed filled with clean sand into a biological filter. Therefore, the writer holds it to be necessary, and is justified in doing so by the success obtained in Bremen, that only filters which have been operated with raw water can be used as final filters.

Granted the theory is right, that a ripe filter with a certain filtering velocity can completely purify raw water containing a definite amount of impurities, it might then be said that it should be possible just as completely to purify a worse raw water by correspondingly reducing the filtering velocity. This is true, but a simple computation will show that the possibility of reducing this velocity in practice soon reaches an end.

The area of the filter surface which should suffice for double filtration must be determined from the special conditions of the country and the stream where filtration is required. In Germany, particularly in Bremen, at the Lower Weser, a stream which carries very variable water, and several times both in spring and fall brings very turbid water to the pumping station, the filter area required for the greatest summer consumption with single filtration is sufficient also for double filtration, because during high-water periods in spring and fall the rate of water consumption is much smaller than the yearly maximum.

Generally speaking, for double filtration it is necessary to compute the filter area, first for the maximum delivery with single filtration and then for the possible maximum at times of high water. The larger of the two areas should be chosen. It is correct to introduce into this calculation different filter velocities for single or double filtration; namely, for the single filtration 63 to 100 mm. per hour, and for the double about 100 mm. or more per hour, depending upon special considerations. In Bremen it was found that, with a velocity of 200 to 250 mm. per hour, the final filters occasionally did favorable work.

It will never be necessary to have as much as twice the area for double as for single filtration, and it is always possible to obtain a considerable advantage, even if the filter area is not increased at all, that is, if a second filtration is effected only at those times when the area is really available therefor, as when the consumption is low or after cleaning and refilling; for which purposes, in any event, reserve areas must be available.

By double filtration all is secured that can reasonably be expected from water purification, and chemical assistance is superfluous, but the discoloration caused by humic combinations, which should be distinguished from turbidity, cannot wholly be removed; filtrates from peaty water will retain a slight brownish color unless chemical means are used. The writer has preferred to retain the color if the filtrates were perfectly clear.

In Bremen the water formerly filtered by single filtration contained during every flood 1 000 to 3 000 bacteria, instead of the permissible 100, and was quite turbid besides. Since the introduction of double filtration the city receives, also during floods, a clear filtrate with not more than about 100 bacteria per cubic centimeter. Because double filtration follows single filtration, the final

filters are always in best condition for effective filtration, that is, they are ripe. The entire filter area is very thoroughly utilized, because in summer a large consumption is coincident with a small bacterial content, and the entire filter area can be used for single filtration to secure the full hygienic effect; while during fall and spring the more difficultly filtered raw water is coincident with a smaller consumption, allowing, therefore, on account of the more ample area, a part of the filter area to be used as preliminary and the remainder as final filters. In Bremen, the new area, designed in the year 1892, for single filtration, did not have to be enlarged when in 1895 double filtration was introduced.

All existing filters are in continuous service, including the reserve filters. The difference in the quantity of water consumed is met by a careful change in the filter velocity, as far as the clear-water reservoirs are not capable of compensating for these variations.

The maximum yield of filtered water was 2.4 cu. m. in 24 hours per square meter of filtering surface. The average yield for the year 1900-01 was 1.54 cu. m., and in the year 1901-02, 1.67 cu. m.

The filtering periods between consecutive cleanings range from a minimum, at a time of high water, of about 7 days to a maximum of about 120 days, the average being about 30 to 35 days. During the maximum periods the filters are generally used for quite a time as final filters, during which the loss of head increases very little or not at all.

The loss of head directly after cleaning is about 3 to 5 cm., and it increases until at the end of the period it is about 70 cm.

At each cleaning there is removed from 2 to 3 cm. of sand; that is, in the case of a filter having a surface area of 1 200 sq. m., the total volume of sand removed ranges from 24 to 36, and averaging 30 cu. m. The scraping of a filter of this size is done by ten men in ten working hours.

The sand is not transported from the filter to the sand-washer at the time of scraping, but is moved at some other convenient time. In a similar manner, the washed sand is transported from the washing plant to the clean-sand pile as convenience allows.

Sand-washing facilities, with storage areas, must be provided at filter-works. In Bremen, washers of the revolving-drum type are used. The

wash-water operates a (patented) water motor which drives the drums and the sand elevator. The general arrangement of the plant, which was designed by the writer, is shown in Fig. 2, Plate XLVII.

In washing the sand with this newest sand-washer, the services of one man are necessary. He washes in one hour 2 cu. m. of sand, using 7 to 8 volumes of water to 1 volume of sand. This record of the water used includes, not only that used in the washer itself, but also that necessary for turning the wash-drum and in operating the sand-elevator. The pressure of the water used for washing is from 30 to 35 lbs.

The injector system of washing, used at some places in England and America, also in Hamburg, requires 20 to 30 cu. m. of water for 1 cu. m. of sand. The larger consumption of water in this case is due to the fact that the water and sand move in the same direction, while the advantage of the drum washing is due to the fact that these directions are opposite. The advantages formerly accredited to the injector system, namely, that only the wash-water was required for them, that they could easily be decentralized, and that, therefore, there was a saving in the transportation of sand, are now exceeded by the system of drum washing, because the quantity of water which must be brought to the site through pipes is much smaller.

In refilling filters with the clean, washed sand, including the transportation from the clean-sand pile to the filter and spreading it upon the latter, there are required for each cubic meter of sand from 3 to 3½ hours' labor for one man.

The entire operation of the filters, consisting of cleaning, refilling, sand washing, and expense for double filtration, costs in Bremen, for 1 cu. m. of filtered water, annually, 0.166 pf. ($1.52 per million U. S. gallons). The entire annual cost of the water, including maintenance of the distribution system, which for German conditions is quite elaborate, including also interest and sinking fund, which together are reckoned at 6½%, is 8.4 pf. (2.1 cents) for 1 cu. m. delivered into the high-level reservoir, or about $75 per million U. S. gallons. The wages of a common laborer are 3.5 marks ($0.84) per day.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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DOCK IMPROVEMENTS AT LIVERPOOL.

By George Cecil Kenyon, Assoc. M. Am. Soc. C. E.

To be Presented November 18th, 1903.

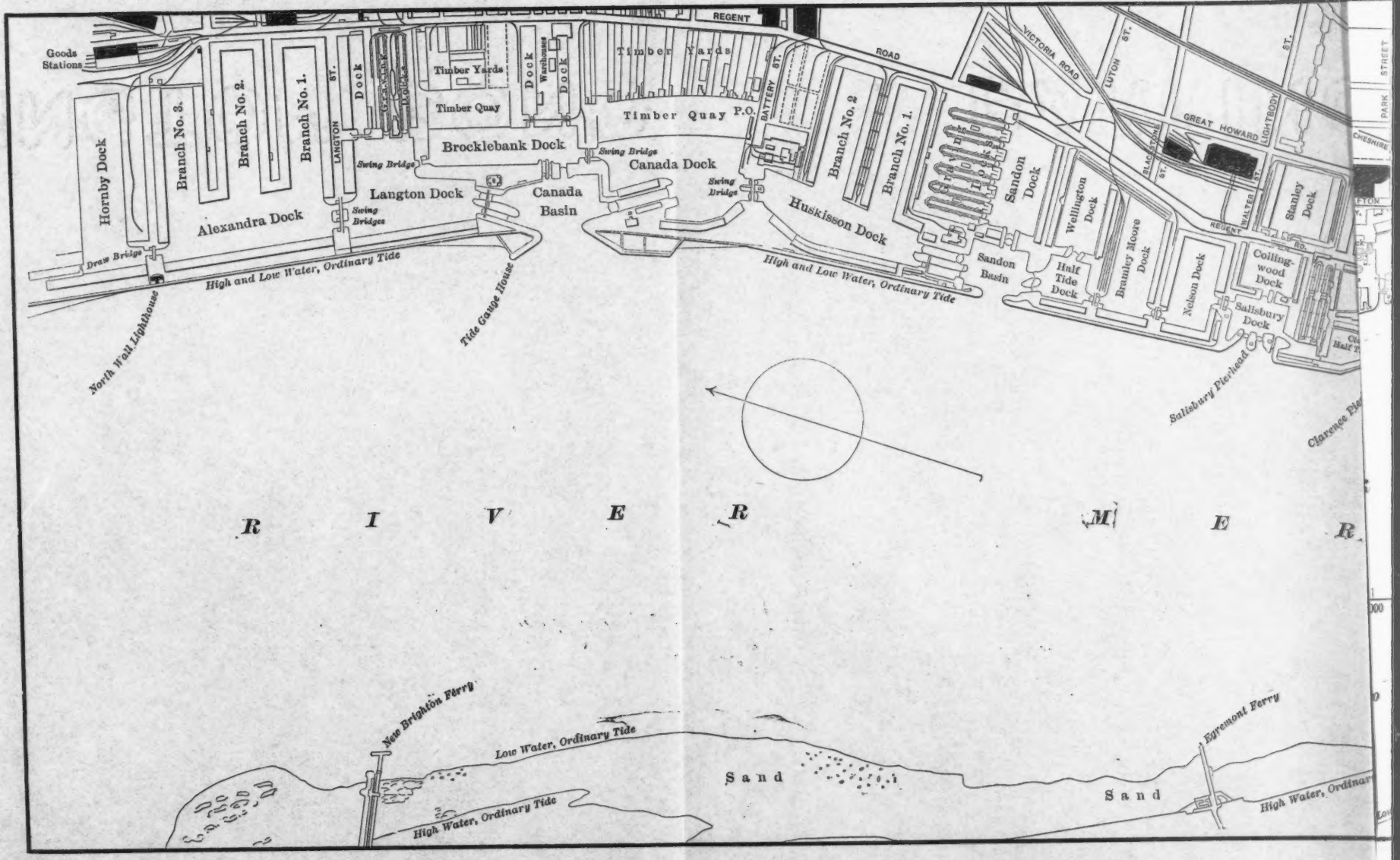
This paper, which describes the works now in progress in connection with the construction of new deep-water entrances at Brunswick Dock, Liverpool, has been written in the belief that a comparison of English and American methods of dock construction will be of interest to the membership of the American Society of Civil Engineers.

Anthony George Lyster, M. Inst. C. E., Engineer-in-Chief to the Mersey Docks and Harbour Board, is responsible for the design, which is being carried out under his direction, the writer acting as Resident Engineer.

As will be seen from Plate XLVIII, the Liverpool Dock Estate consists of two independent dock systems, the southern system being served by eleven entrances from the river.

It having been decided to remodel the southern system by the construction of new deep-water docks and the deepening of some of the existing docks, new deep-water entrances became part of the scheme, as it will be obvious, by reference to Table No. 1, that the

Note.—These papers are issued before the date set for presentation and discussion Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.


Goods Stations
Hornby Dock
Branch No. 3.
Branch No. 2.
Branch No. 1.
LANGTON ST.
Dock
Timber Yards
Timber Quay
Brocklebank Dock
Swing Bridge
Langton Dock
Swing Bridges
Alexandra Dock
Draw Bridge
High and Low Water, Ordinary Tide
North Wall Lighthouse
Tide Gauge House
Dock Warehouses
Timber Yards
Timber Quay
Canada Dock
Swing Bridge
Canada Basin
Swing Bridge
REGENT ROAD
BATTERY ST.
P.O.
Branch No. 2
Branch No. 1.
Huskisson Dock
Sandon Dock
Wellington Dock
Sandon Basin
Half Tide Dock
Brunley Moore Dock
Nelson Dock
Collingwood Dock
Salisbury Dock
Stanley Dock
VICTORIA ROAD
LUTON ST.
GREAT HOWARD ST.
LIGHTBODY ST.
BLACKSTONE ST.
WALTER ST.
REGENT RD.
CHESHIRE STREET
PARK
Salisbury Pierhead
Clarence Pier
R I V E R M E R
New Brighton Ferry
Low Water, Ordinary Tide
High Water, Ordinary Tide
Sand
Sand
Egremont Ferry
High Water, Ordinary

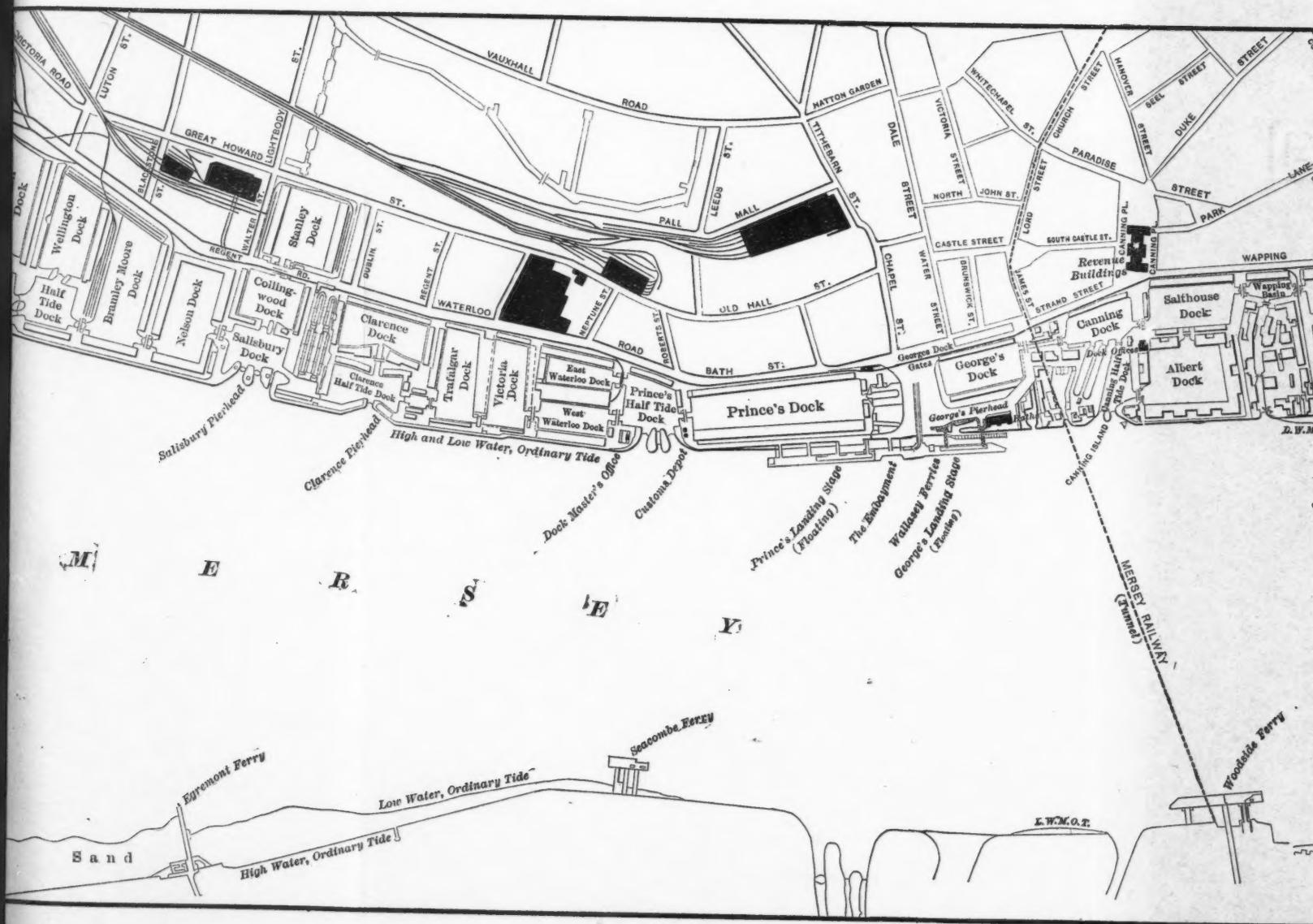
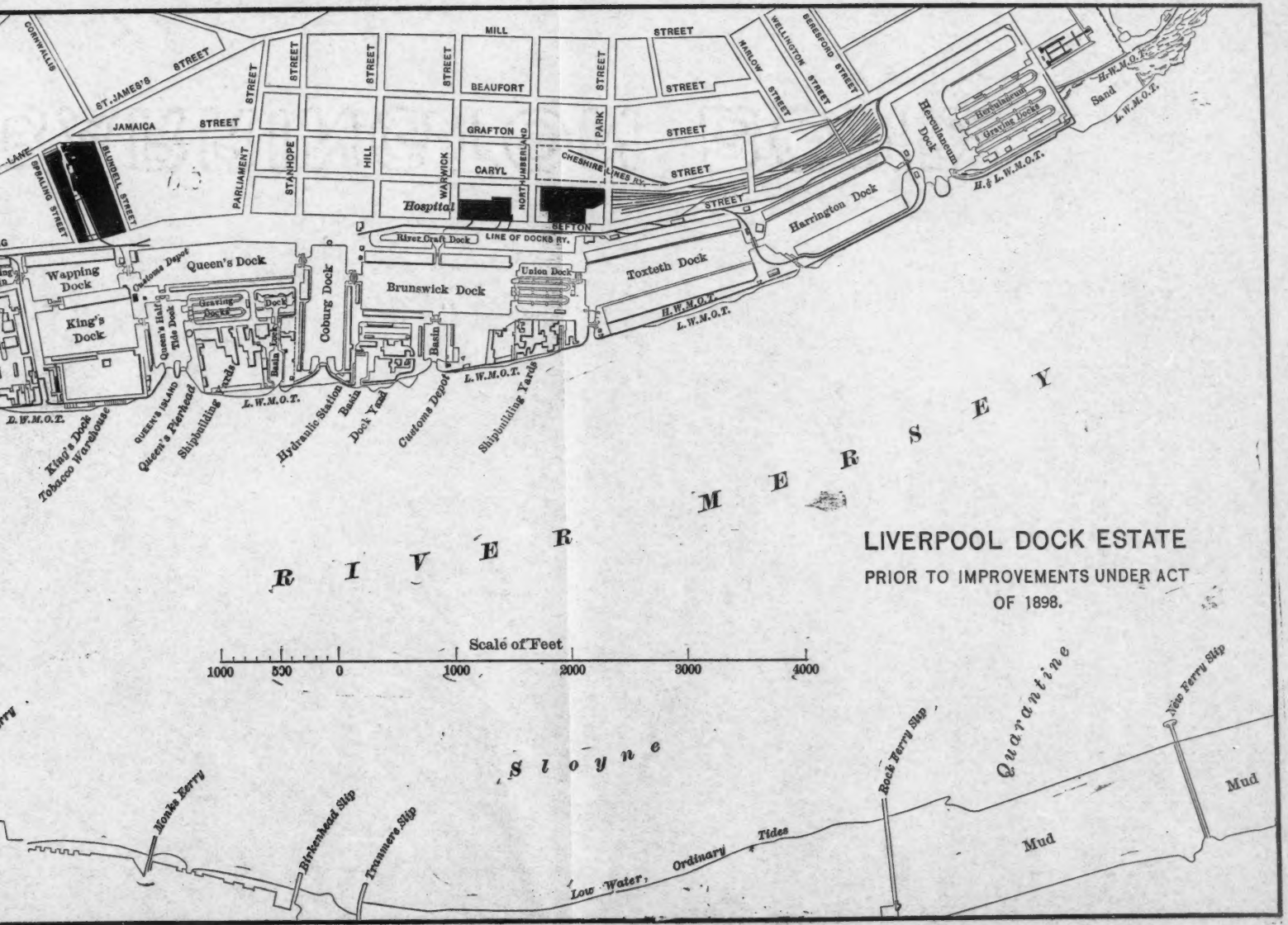

VICTORIA ROAD
LUTON ST.
GREAT HOWARD ST.
LIGHTBODY ST.
BLACKSTONE ST.
WALTER ST.
REGENT RD.
DUBLIN ST.
REGENT ST.
VAUXHALL ROAD
PALL MALL
LEEDS ST.
HATTON GARDEN
TITHEBARN ST.
DALE STREET
VICTORIA STREET
NORTH JOHN ST.
CASTLE STREET
WATER STREET
CHAPEL ST.
OLD HALL ST.
BATH ST.
WATERLOO ROAD
NEPTUNE ST.
ROBERTS ST.
BRUNSWICK ST.
JAMES ST.
STRAND STREET
LORD STREET
SOUTH CASTLE ST.
CANNING PL.
WHITECHAPEL ST.
CHURCH STREET
HANOVER STREET
SEEL STREET
DUKE STREET
PARADISE STREET
PARK LANE
WAPPING
Dock
Wellington Dock
Half Tide Dock
Bramley Moore Dock
Nelson Dock
Collingwood Dock
Salisbury Dock
Stanley Dock
Clarence Dock
Clarence Half Tide Dock
Trafalgar Dock
Victoria Dock
East Waterloo Dock
West Waterloo Dock
Prince's Half Tide Dock
Prince's Dock
George's Dock Gates
George's Dock
George's Pierhead
Revenue Buildings
Canning Dock
Dock Offices
Canning Half Tide Dock
Albert Dock
Salthouse Dock
Wapping Basin
Salisbury Pierhead
Clarence Pierhead
High and Low Water, Ordinary Tide
Dock Master's Office
Customs Depot
Prince's Landing Stage (Floating)
The Embayment
Wallasey Ferries
George's Landing Stage (Floating)
CANNING ISLAND
MERSEY RAILWAY (Tunnel)
MERSEY
Seacombe Ferry
Egremont Ferry
Low Water, Ordinary Tide
High Water, Ordinary Tide
Sand
L.W.M.O.T.
Woodside Ferry

PLATE XLVIII.
PAPERS, AM. SOC. C. E.
SEPTEMBER. 1903.
KENYON ON LIVERPOOL DOCK
IMPROVEMENTS.



existing river entrances, with the exception of the Herculaneum, are only suitable for comparatively small and shallow vessels, and are quite inadequate to provide means of access for the large type of cargo steamer now in vogue.

The scheme of reconstruction (see Plate XLIX), for which an Act of Parliament was obtained in 1898, includes, in brief, the construction of deep-water entrances to the Brunswick Dock; the deepening of the Brunswick Dock and the underpinning of its walls in order that it may be used as a half-tide dock, or vestibule to the reconstructed system; the construction of a branch dock at the south end of the Brunswick Dock; the construction of a single-story shed on the east quay of the Brunswick Dock; the reconstruction of the passage between the Brunswick and Toxteth Docks; the widening and deepening of the passages between the Brunswick and Coburg Docks and the Coburg and Queen's Docks, respectively, and the deepening of the Coburg Dock between these two passages; the straightening of the north quay of the Coburg Dock; the deepening of the Queen's Dock and the construction on the west side of it of a graving dock and two branch docks with double-story sheds; the widening and deepening of the passage between the Queen's and Wapping Docks; and the construction of two branch docks with double-story sheds on the west side of the Wapping Dock.

The work done has been as follows: The east quay of the Brunswick Dock has been underpinned; the north quay of the Coburg Dock has been straightened; the passages between the Brunswick and Coburg Docks, and the Coburg and Queen's Docks have been widened and deepened, and the southern branch dock on the west side of the Queen's Dock has been completed.

At the present time, in addition to the new river entrances, the north branch dock and graving dock on the west side of the Queen's Dock are in course of construction.

In consequence of the last-mentioned works, the north and south entrances to the Queen's Half-Tide Dock, which have a width of 70 and 50 ft., respectively, and sills laid at 6 ft. 9 ins. below and copings at 31 ft. above datum, are permanently out of commission.

The river entrance to the Brunswick Half-Tide Dock has also been withdrawn from use, as far as the southern system of docks is concerned, as this dock is now used solely as a repairing dock by the

Mersey Docks and Harbour Board, and has no connecting passage with the Brunswick Dock.

At the completion of the works involved by the present scheme, the southern system of docks will be served by the entrances from the river, shown in Table No. 1.

TABLE No. 1.

Dock or Lock.	Width of entrance.	Sill below datum.	Copings of hollow quoins above datum.
Canning Half-Tide Dock, North	45 ft.	6 ft. 3 ins.	28 ft. 3 ins.
Canning Half-Tide Dock, South	45 "	6 " 3 "	28 " 3 "
Duke's Dock	40 "	4 " 2 "	25 " 10 "
Coburg Dock	70 "	5 " 7 "	30 " 6 "
Brunswick Lock (240 ft. long), North	80 "	19 " 0 "	33 " 0 "
Brunswick Lock (350 ft. long), South	100 "	19 " 0 "	33 " 0 "
Toxteth Lock (177 ft. long)	50 "	8 " 0 "	31 " 0 "
Harrington Lock (131 ft. long)	22 "	5 " 9 "	31 " 0 "
Herculaneum Dock, North	80 "	12 " 0 "	31 " 0 "
Herculaneum Dock, South	60 "	12 " 0 "	31 " 0 "

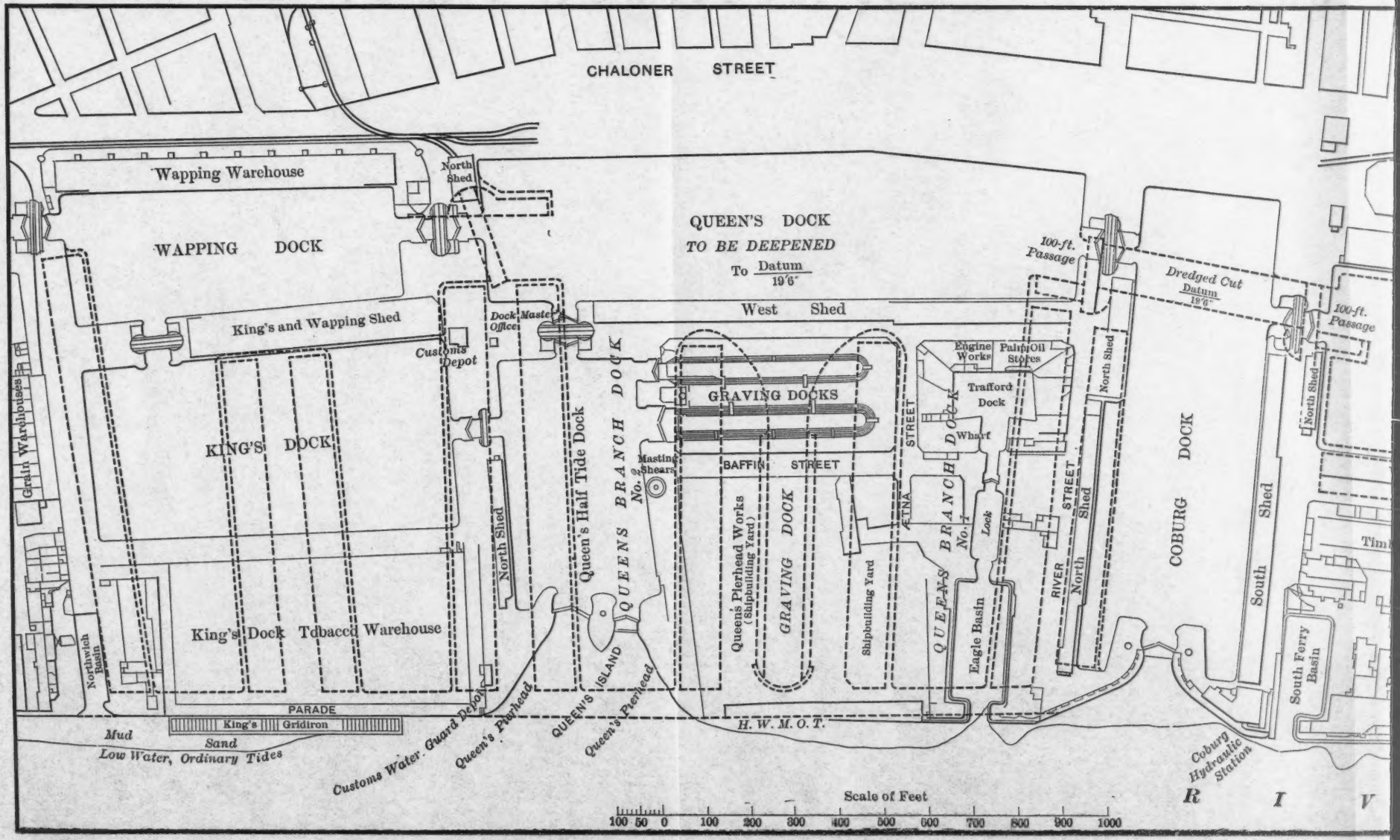
The new entrances have the additional advantage of allowing vessels to be passed to and from the docks for a much longer period during each tide than was formerly the case.

Any loss of water which may take place under the new conditions, through locking, etc., and on neap tides, will be made good by pumping from the river with three 56-in. centrifugal pumps, the pumping station being situated at the southwest corner of the Coburg Dock.

The new entrances, consisting of two locks, run in a northerly direction from the river and at an acute angle with the general line of the river wall. This is the direction now generally adopted at Liverpool as being the most suitable for passing vessels between the docks and the tideway.

The eastern lock is 350 ft. long, between centres of hollow quoins, and 100 ft. 1 in. wide; and the western lock is 240 ft. long, between centres of hollow quoins, and 80 ft. 1 in. wide.

The level of the gate sills in both locks is 19 ft. 6 ins. below datum, and as 6 ins. are deducted on account of the gate-closing chains, which cross the sills, the working depth is 19 ft. below datum. On comparing the working depth with the figures given in Table No. 1, it will be seen that there is a minimum depth of 9 ft. of water on the sills at low water of spring tides.


CHALONER STREET
Wapping Warehouse
North Shed
WAPPING DOCK
QUEEN'S DOCK
TO BE DEEPENED
To Datum 19'6"
100-ft. Passage
Dredged Cut Datum 19'6"
100-ft. Passage
King's and Wapping Shed
Dock Master's Office
Customs Depot
West Shed
Engine Works
Palm Oil Stores
North Shed
Grain Warehouses
GRAVING DOCKS
Trafford Dock
KING'S DOCK
QUEENS BRANCH DOCK No. 2
Queen's Half Tide Dock
Masting Shears
BAFFIN STREET
ETNA STREET
Wharf
QUEENS BRANCH No. 1
Lock
RIVER STREET
North Shed
COBURG DOCK
North Shed
South Shed
Queen's Pierhead Works (Shipbuilding Yard)
GRAVING DOCK
Shipbuilding Yard
Eagle Basin
King's Dock Tobacco Warehouse
Northwich Basin
PARADE
King's Gridiron
Mud
Sand
Low Water, Ordinary Tides
Customs Water Guard Depot
Queen's Pierhead
QUEEN'S ISLAND
Queen's Pierhead
H. W. M. O. T.
South Ferry Basin
Coburg Hydraulic Station
Scale of Feet
100 50 0 100 200 300 400 500 600 700 800 900 1000
R I V

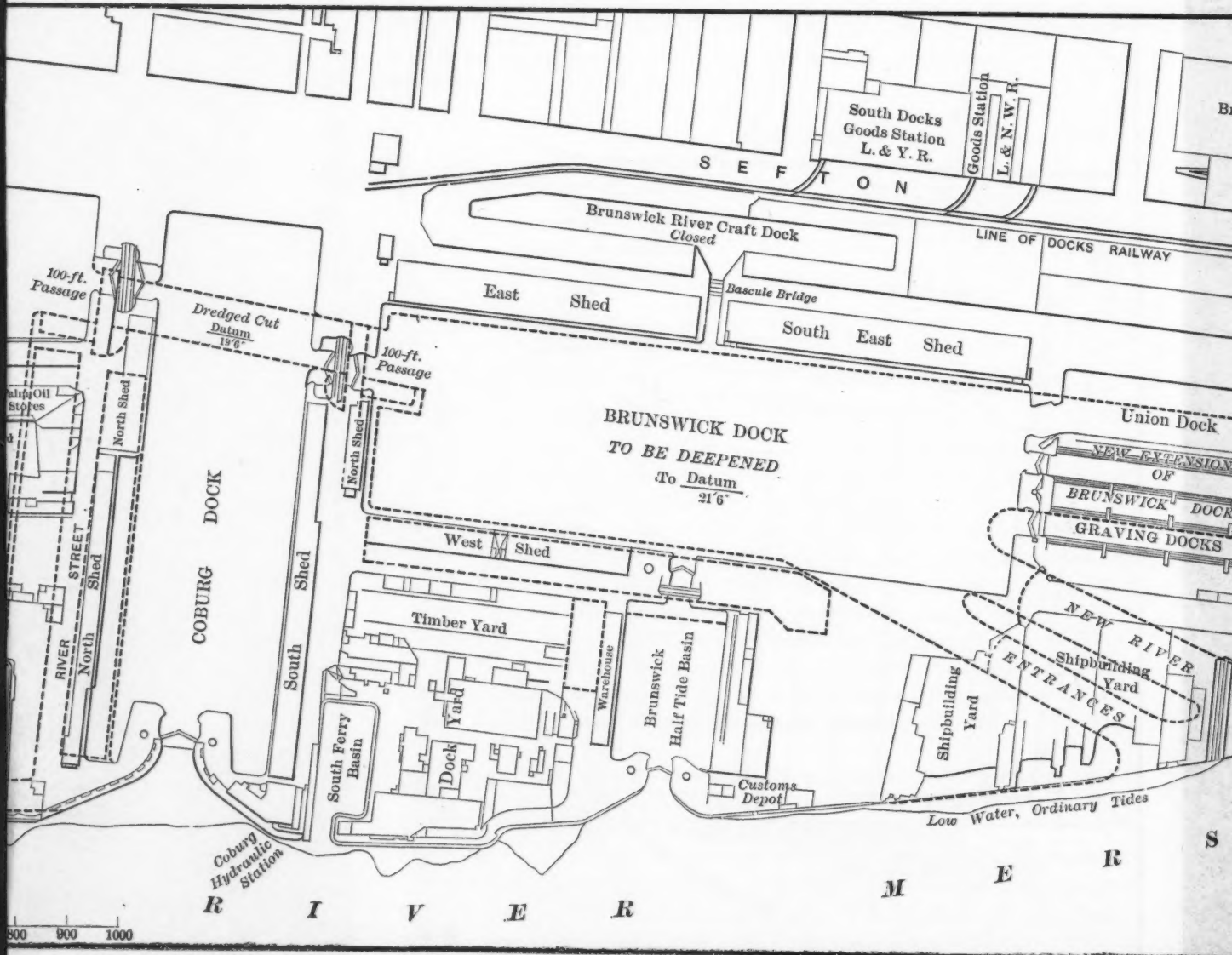
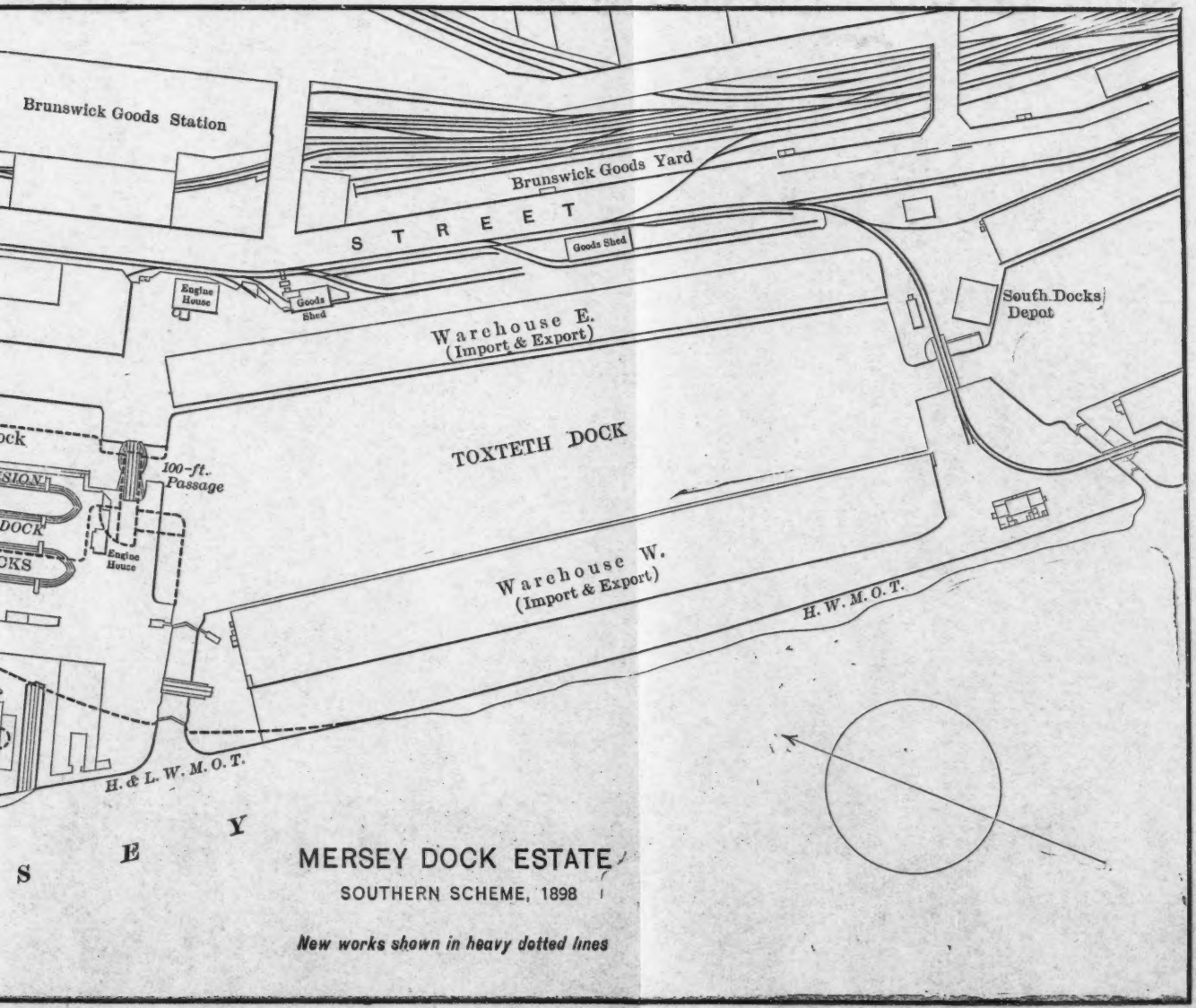

South Docks
Goods Station
L. & Y. R.
Goods Station
L. & N. W. R.
SEFTON
Brunswick River Craft Dock
Closed
LINE OF DOCKS RAILWAY
100-ft. Passage
Dredged Cut
Datum
19'6"
East Shed
Bascule Bridge
South East Shed
100-ft. Passage
North Shed
BRUNSWICK DOCK
TO BE DEEPENED
To Datum
21'6"
Union Dock
NEW EXTENSION OF BRUNSWICK DOCK
GRAVING DOCKS
North Shed
COBURG DOCK
RIVER STREET
North Shed
South Shed
West Shed
Timber Yard
Dock Yard
Warehouse
Brunswick Half Tide Basin
South Ferry Basin
NEW RIVER ENTRANCES
Shipbuilding Yard
Shipbuilding Yard
Customs Depot
Low Water, Ordinary Tides
Coburg Hydraulic Station
RIVER MERSEY
800
900
1000

PLATE XLIX.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1903.
KENYON ON LIVERPOOL DOCK
IMPROVEMENTS.



MERSEY DOCK ESTATE.

SOUTHERN SCHEME, 1898

New works shown in heavy dotted lines

The level of the coping is 33 ft. above datum, the lock floors and gate platforms being laid at a level of 22 ft. 9 ins. below datum.

The island between the locks varies in width from 65 ft. at the river end to 55 ft. at the dock end. Running longitudinally through the island and side walls there are levelling culverts, which will also serve for sluicing purposes. See Fig. 1, Plate L.

There are two pairs of gates to each lock, the operation of opening or closing any pair occupying about two minutes. The hydraulic power for gate machinery, etc., is obtained from the Boards' own mains, under a pressure of about 800 lbs. per square inch, the diameter of the pressure pipes being 6 ins. and of the return-water pipes 7 ins.

The gate recesses, Fig. 1, Plate LII, are corbelled over, the coping of the corbels being set to the same alignment as the walls of the locks.

At the back of and parallel to the side-walls are retaining walls (see Fig. 2, Plate LII), the intervening space being filled in so as to form a continuous terrace, 40 ft. wide, on the roadside of which are ornamental cast-iron railings.

These terraces have been formed with the object of giving greater facilities, in the docking of modern vessels, than would obtain if the copings had been constructed at the ordinary quay level, *i. e.* 27 ft. above datum.

Steel drawbridges give pedestrian access to and across the island.

The datum level referred to throughout this paper is 4 ft. 8 ins. below ordnance datum. The following are particulars of the average levels of certain tides, etc., with regard to this datum:

Average high-water mark of ordinary neap tides	11 ft.	7 ins.	above datum.
Average high-water mark of ordinary spring tides, excluding equinoctial tides	18 "	10 "	"	"
Average high-water mark of equinoctial spring tides	21 "	1 "	"	"
An extraordinary high-tide, January 20th, 1863	23 "	9 "	"	"
An extraordinary high tide, February 13th, 1899	24 "	0 "	"	"
Mean tide level	4 "	8 "	"	"
Average low-water mark of ordinary neap tides	1 "	5 "	below datum.	

Average low-water mark of ordinary spring tides, excluding equinoctial tides..... 8 ft. 8 ins. below datum.
Average low-water mark of equinoctial spring tides.....10 " 0 " " "

It is not anticipated that during the construction of the entrances it will be necessary to run dry any of the adjoining docks for the purposes of, or in connection with, the works; the water being maintained at the ordinary working level.

It was known, however, that these docks might have to be run dry at some time during the progress of the work, for repairs to gates, walls, etc., and the possibility of this was borne in mind and provision made against all risks of damage arising therefrom.

During the progress of the work, when artificial light is required for any length of time, illumination is obtained by ordinary gas lamps, and in other cases by the Lucigen type of portable lamp.

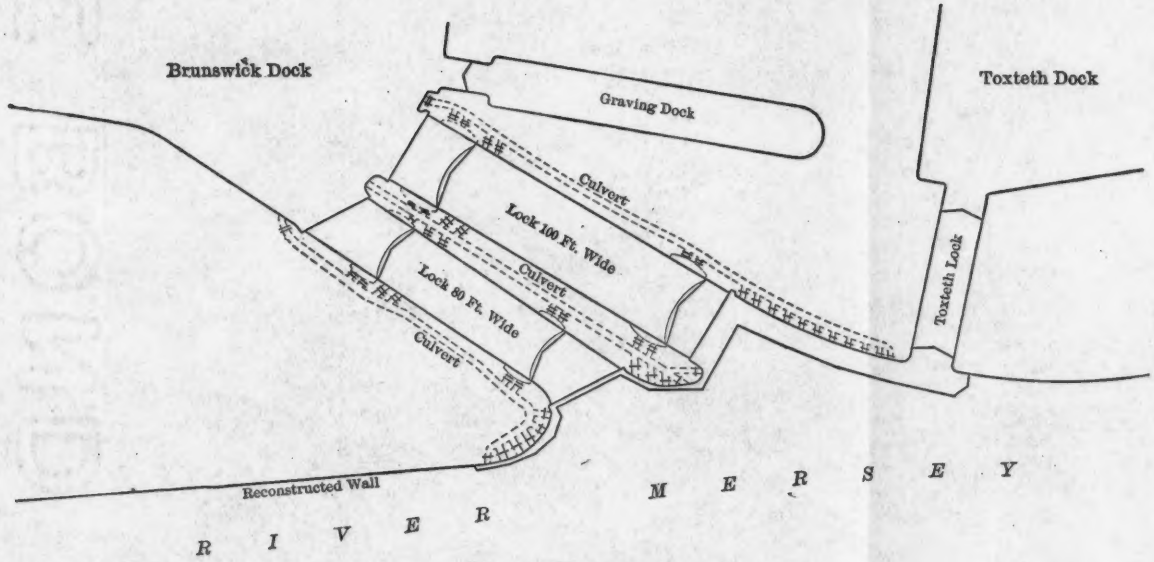
The site of the new entrances had formerly been used for shipbuilding and repairing purposes, and the old river wall had been carried up to an average level of about 10 ft. above datum. There was also an old entrance in the wall leading to a small dock.

Before commencing the work proper it was necessary to raise temporarily the river wall (see Fig. 2, Plate L) to prevent the tide from flooding the works. The reconstruction of the northern portion of this wall was part of the scheme of improvement, and it was decided, therefore, to proceed with this work immediately. The line of the new wall being about 2 ft. in front of the old wall, the latter was faced with concrete to that extent, and the work of reconstruction completed by raising the whole in 8 to 1 concrete to the level of 26 ft. 6 ins. above datum. For the reconstruction of the river wall, a staging, forming a crane and wagon road, was erected about 2 ft. behind the line of the back of the new wall.

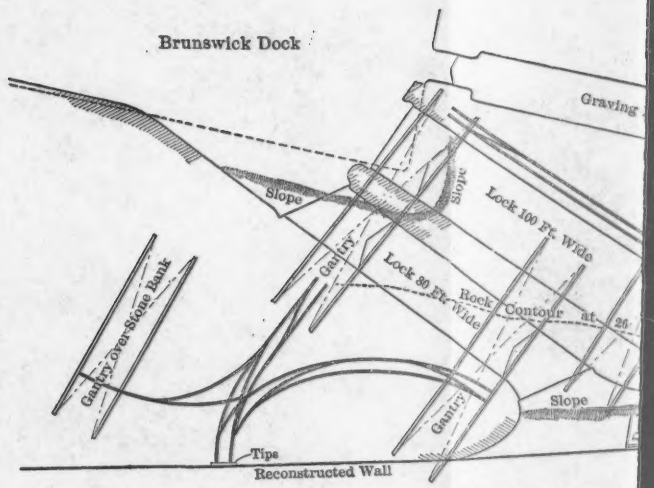
From the south end of this staging, a temporary railway was laid to the Brunswick Dock, where gravel, etc., for concrete, was discharged; a branch line was also laid to the cement stores.

To enable the faced portion of the reconstructed wall to be put in, a trench was sunk in front of the wall, and for pumping this out hand chain-pumps were used.

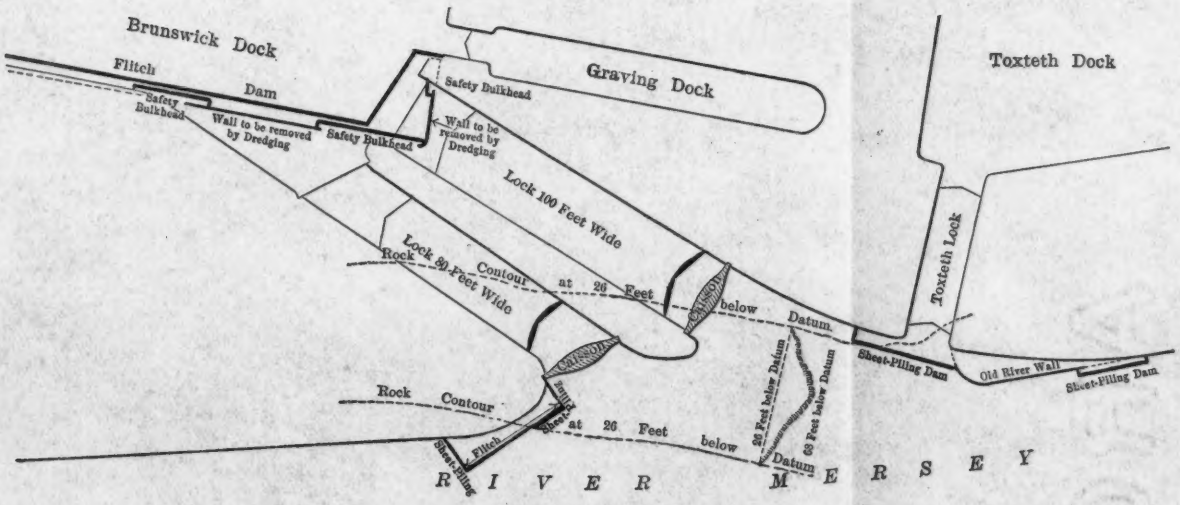
For timbering the trench, ordinary vertical poling boards with deal walings were used, the latter being strutted to the old wall.



BRUNSWICK LOCKS.
GENERAL PLAN OF THE ENTRANCES, SHOWING CULVERTS.
FIG. 1.



BRUNSWICK LOC
THE HATCHED PORTIONS OF THE WALL
WHEN THE WATER WAS LET INTO
FIG. 2.



BRUNSWICK LOCKS.
SYSTEM OF DAMS SUBSEQUENT TO REMOVAL OF RIVER WALL.
FIG. 3.

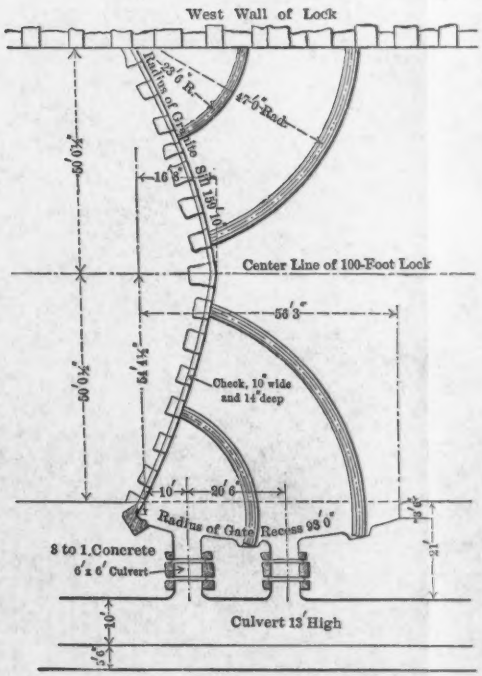
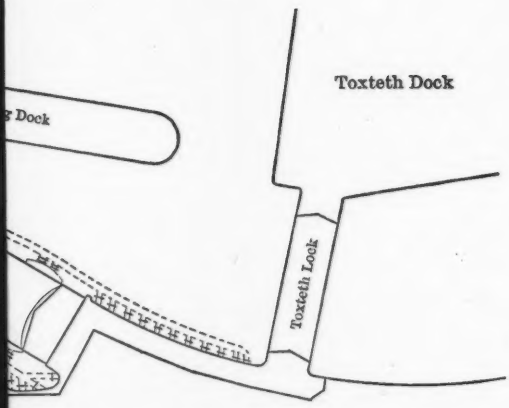


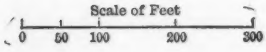
FIG. 4.

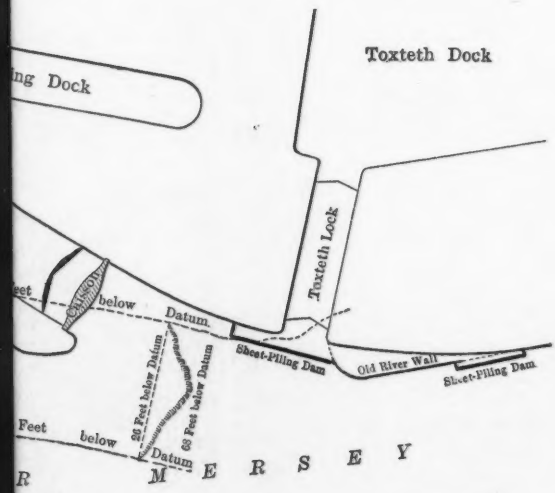




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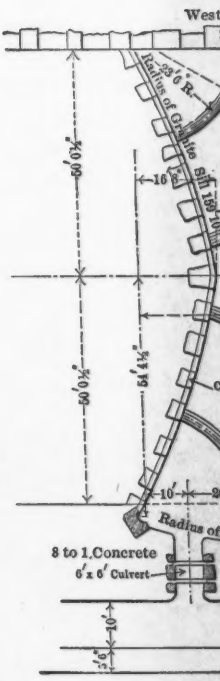
KS.
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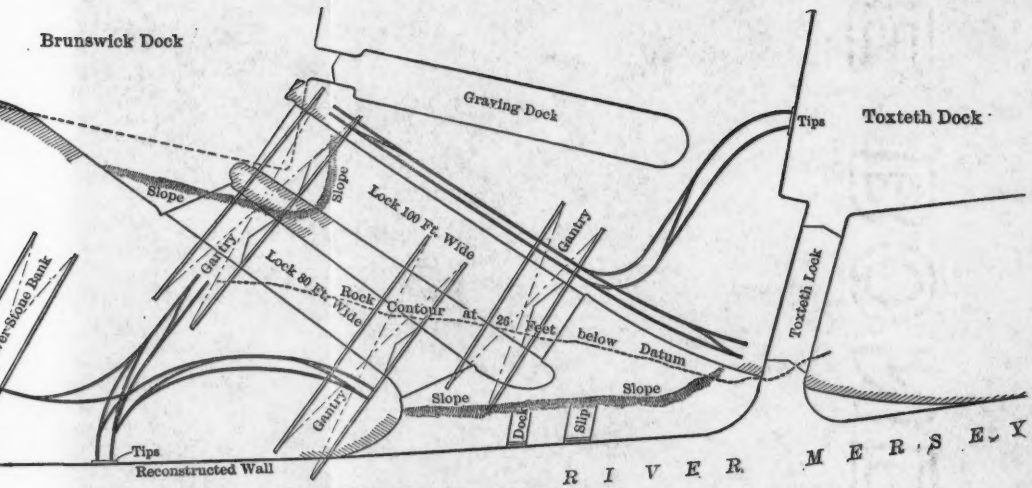




R M E R S E Y

OCKS.
REMOVAL OF RIVER WALL.

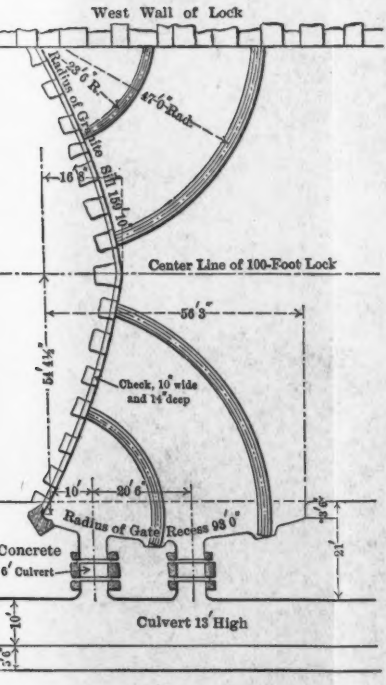




BRUNSWICK LOCKS.

THE HATCHED PORTIONS OF THE WALLS WERE NOT FOUNDED WHEN THE WATER WAS LET INTO THE WORKINGS.

FIG. 2.



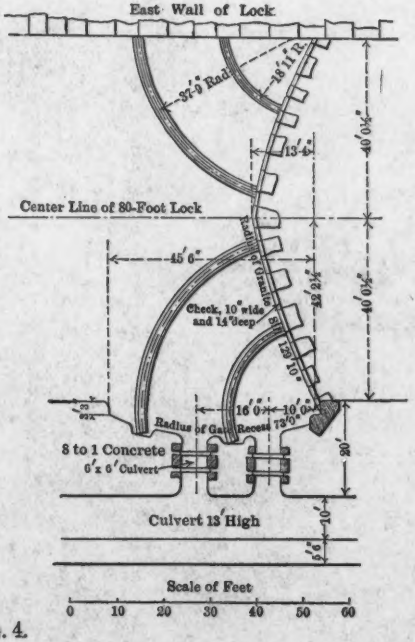


FIG. 4.

For bonding the new concrete with the old wall, dovetailed pockets, 2 ft. wide at the face, 2 ft. 9 ins. wide at the back, and 1 ft. 3 ins. deep, were cut vertically in the old masonry, 4 ft. apart.

"Soldiers" and shutters were used in moulding the concrete at the face of the wall, and, at the back, the altar-courses were formed with "plums."

Simultaneously with the reconstruction of the river wall, the work of sinking the pump-well was in hand. Chain-pumps having four sets of reels, with buckets 2 ft. long, were used, the reels being arranged to work independently or together. The site selected for the pumps was at the northwest corner of the 80-ft. lock.

Anticipating that the general foundation level would be about 27 ft. 6 ins. below datum, the well was sunk to an additional depth of 10 ft., it being thought that this would be ample for all drainage purposes.

The engine and boilers for driving the pumps were placed in the rear of the trench for the west wall of the 80-ft. lock, at a sufficient distance beyond the angle of natural repose, taken from rock level, to prevent the possibility of the engine foundations being affected by any fretting of the ground caused by trenching operations.

The power was transmitted to the reels by means of a shaft made up of sections with claw couplings, which allowed for settlement of the intermediate bearings without undue strain on the shaft.

The chain-pump well was sufficiently large to enable the whole of the framing carrying the reels, etc., to be put in before commencing the general excavation, it being intended that the original framing should remain without alteration until the completion of the work.

The intermediate bearings of the shafting were carried on needles, supported by piles braced longitudinally and laterally, those piles coming in the wake of the trench being underpinned and legged up as the work of trenching proceeded. The water from the pumps was discharged into the river, a distance of 380 ft.

From the south end of the reconstructed wall, and extending southward along the old wall, a making-up dam was formed of concrete blocks to raise the level to 24 ft. above datum. The wall was brought up, with 10 to 1 concrete, to a uniform level to form a foundation on which to lay the blocks.

Blocks which had been used previously at other works were then

built up in courses, with mortar and brown-paper joints, and, when these were used up, other blocks were formed in position by placing shutters across the empty spaces between the headers and filling in with concrete, the bed and sides forming the moulds being well greased to prevent adhesion.

For setting the concrete blocks, a staging, forming a crane road, was erected at the back of the old wall. This road was also connected to the railroad leading to Brunswick Dock. The blocks were there discharged into wagons from flats and conveyed to the required positions by way of the above railroad.

The entrance to the small dock, previously referred to, was closed by horizontal whole-balk timbers, arranged to form a dam, the seams being caulked.

A timber dam was also placed in a gap forming an entrance to an old repairing slip, vertical deals, 3 ins. thick, with caulked seams, being spiked to walings spaced to suit the water pressure.

The method of disposing of the excavated material was by sending it to sea in the Board's steam hopper-barges. The distance, on the sailing line, to the dumping site is about 26 statute miles, the round trip occupying about 8 hours.

The hoppers loaded at the river tips sailed each tide, those loading in dock every alternate tide. End-tip wagons, holding about 4 cu. yds., were used in conveying the excavated material from the filling site to the loading berths, the wagons being hauled to the neighborhood of the tips by means of horses and tipped by "galloping out."

The east wall of the 100-ft. entrance and the west wall of the 80-ft. entrance were constructed in trenches, and, after their completion, the general excavation was removed and the island constructed. To minimize the risk of the trenches being flooded, it was considered advisable to terminate them at a distance of about 50 ft. from the old walls.

As anticipated, from borings taken prior to the commencement of the work, rock was found in the east trench about 12 ft. below datum, or 13 ft. 6 ins. above foundation level. The material was removed from this trench by means of skips, having a capacity of 2 cu. yds., which were raised by means of 5-ton steam-locomotive cranes working at both sides of the trench.

Parallel to the crane roads were full and empty wagon roads con-



FIG. 1.—NEW ENTRANCE TO BRUNSWICK DOCK.

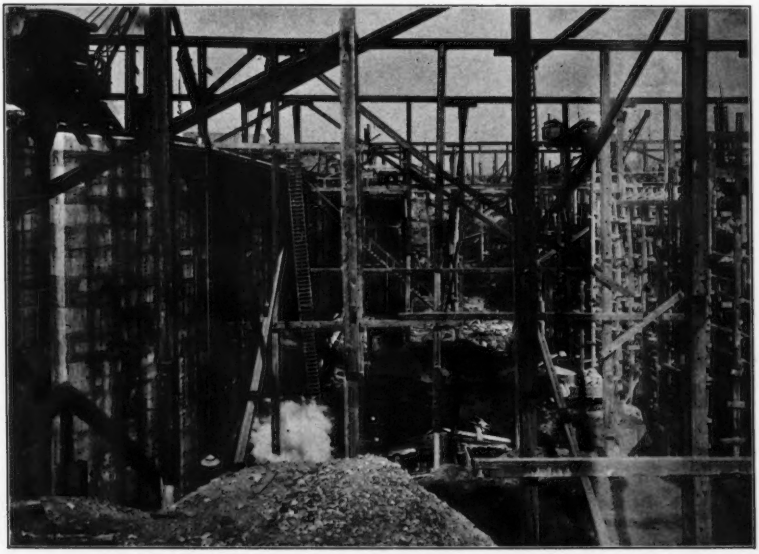


FIG. 2.—NEW ENTRANCE TO BRUNSWICK DOCK. 80-FOOT LOCK.

nected by loops, these roads leading to a double tip-head at the Toxteth Dock, where the excavated material was loaded into hoppers. The roads were laid out as follows: Centers of crane roads, 5 ft. from the side of the trench; centers of near and far wagon roads, 16 ft. and 27 ft., respectively, from the side of the trench.

Owing to irregularities on the surface of the ground, and the limited space available for crane and wagon roads, the excavated material from the south end of the west trench was removed by means of steam jennies, the wagons being raised directly from the trench and run to the river tip-heads.

At the north end of this trench the excavated material was removed, as in the east trench, by means of cranes, the skips being tipped directly into hoppers berthed in the Brunswick Dock.

The trenches were commenced at a level of 24 ft. above datum, at which level the crane roads, etc., were laid, both trenches being 42 ft. wide over all, at the top setting of the deals. The shores and walings were of pitch pine, 1 ft. square, with walings 4 ft. apart, the struts being placed at 12-ft. centers. The deal runners were 3 ins. thick, and 18 ft. long, the top waling being placed at 1 ft. below the surface level.

The width of the trenches at the top was arranged so that, when rock was met at the expected level, 12 ft. below datum, there would be only about 1 ft. between the deals and the back of the wall at the base, the rock being sawn plumb with the back of the wall.

At the south end of the west trench, after excavating to a level of 30 ft. below datum, and rock not having been found, trial shafts were sunk, and rock was found at a level of 68 ft. below datum. Owing to this fault, which had not been disclosed by the borings, it was decided to found a portion of the wall, within the limits of the fault, on the gravel, at 30 ft. below datum, and to excavate to the greater depth for the foundations of the gate recesses and that portion of the wall south of the same, commencing 10 ft. north of the square quoin.

This involved a maximum lift of about 100 ft. for the excavated material, and, naturally, increased the cost of the work considerably.

It was apparent that the portion of the trench already commenced would become too narrow at the new foundation level, and, to obviate this, all runners then to be put in were placed a little out of the vertical, so that the same width was maintained down to the foundation level.

The extra depth to which the excavation had to be carried also necessitated the provision of an auxiliary pump, to throw water from the deep foundations to the level of the main pump-well. A 15-in. centrifugal pump was used for this purpose, steam being obtained from a boiler at the top of the trench.

With the exception of not finding rock at the expected level, there were no serious difficulties in carrying out the work in the west trench; but in the east trench this was not the case. As the line of the new east wall crossed the Toxteth Lock, the foundations of which were at a higher level than those of the wall, it was necessary to underpin the old work. For this purpose, when the trench had been excavated to the required depth, a heading was continued underneath the lock, the intention being to fill this in with concrete to correspond with the section of the new wall.

In driving this heading, an old constructional drain, 2 ft. in diameter, running longitudinally under the north wall of the lock, was encountered, the western termination of which was found to be in an apron outside the lock.

It was observed that the apron had parted from the river wall, causing an inlet to the drain, which, on being bared, burst, and, consequently, the entire length of the east trench and a small excavation which was being opened by a steam navvy were flooded.

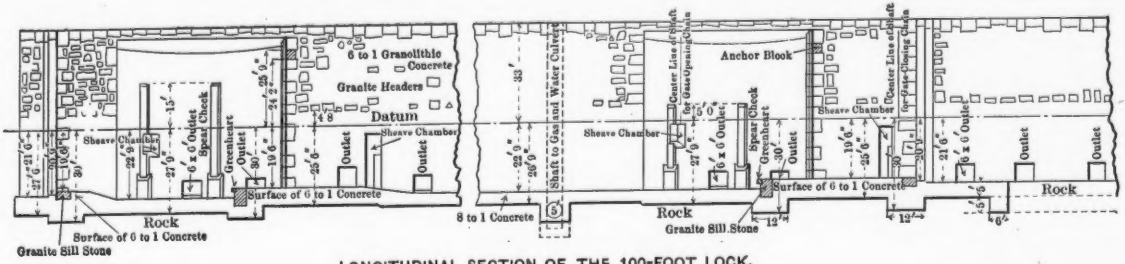
As a safeguard against accidents of this description, a cross-bulkhead had been placed at the south end of the trench, but in spite of this the water found its way beyond the bulkhead.

Ultimately, the drain was plugged effectively by means of a canvas bolster, placed by a diver and filled with grout through a pipe from the surface.

The bolster was designed so that its total weight would be greater than the pressure of the highest tide on the sectional area of the drain.

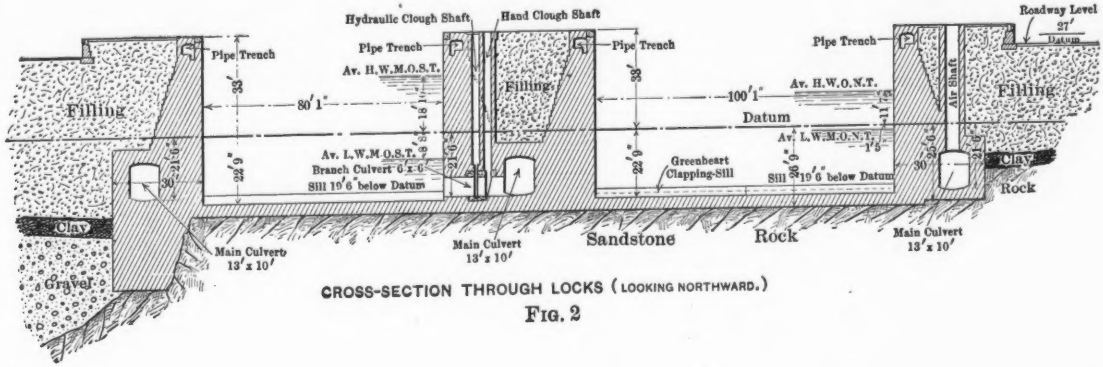
The walls are set out to the curves shown at the coping, and are constructed plumb throughout their whole depth, and where joined to the old walls are thoroughly bonded, the faces of the walls being merged into each other. Between the new and old coping levels, ramps are formed.

The general section of the side-walls is 30 ft. at the base, this width being maintained to 4 ft. below datum, where it sets in to a width of



LONGITUDINAL SECTION OF THE 100-FOOT LOCK.

FIG. 1



CROSS-SECTION THROUGH LOCKS (LOOKING NORTHWARD.)

FIG. 2

18 ft., from which it rises in altar-courses, 2 ft. high and 9 ins. wide, to a minimum width of 8 ft. 6 ins. The near side of the culvert is 14 ft. 6 ins. from the face of the walls, the inverts being laid at a level of 21 ft. 6 ins. below datum.

As regards the island, this is solid, with the exception of the culverts, to a level 4 ft. below datum, from which level the walls are constructed as in the side-walls, the space between the walls at the coping level being covered with concrete 1 ft. thick.

The lock floors are founded at 26 ft. 9 ins., and the gate-sills and caisson-sills at 25 ft. 6 ins. below datum. Under the gate- and caisson-sills, and projecting 3 ft. beyond the face of the same, are stoppers, 12 ft. wide, founded at 30 ft. below datum. The gate platforms are founded at 27 ft. 9 ins. below datum.

Above mean-tide level, the whole length of the new walls, with the exception of the gate recesses, retaining walls and reconstructed river walls, is faced with 1 ft. of 6 to 1 granolithic concrete, in which are set at intervals granite stones with a 2-in. chisel-draft and rough-punched on the face, the sides being dressed to 3 ins. from the face. Such stones are not of less depth than 2 ft. at any part, and are thoroughly incorporated in the surrounding concrete, the aggregate surface of the headers forming not less than one-third of the total surface.

In the vertical faces the two qualities of concrete were placed in their proper respective positions simultaneously, and well trodden together.

The body of the wall and the floors of the chambers are of 8 to 1 concrete. In the back of the walls sheave chambers are formed of 6 to 1 concrete, 2 ft. thick, well worked around the bolts which attach the back plates of the sheaves to the wall.

The method adopted in constructing the east and west walls was as follows: The concrete was first brought up from foundation level to about 1 ft. below formation level, and the front of the walls was then formed by means of concrete moulds, the altar-courses at the back being moulded with deals. As the concrete was brought up, the shores and walings were relieved, the deal runners at the back of the wall being drawn after the filling had been put in to the height of a block setting.

After the moulds had been stripped, and before the shores could be

relieved, it was necessary to secure the timbering in front of the wall, that at the back being supported by the filling.

The concrete was raised in lifts of about 5 ft., two heights of moulds being used in this operation. Only one lift was made per week, the *modus operandi* being as follows: First and second days, mould setting; third day, filling moulds; fourth and fifth days, including Sunday, concrete setting; sixth day, stripping moulds; seventh day, relieving shores.

The walls of the culverts were moulded by means of horizontal deals, supported by deal cross-frames, 5 ft. apart, the concrete being put in evenly so as to obtain equal pressure on either side of the culvert.

The roofs were moulded by means of centers, supported by the verticals of the cross-frames, on which deals were laid to form lagging.

The inverts were formed in panels, in a hit-and-miss manner, after the arching over was completed, the radius being obtained by screeds.

The finished culverts are 10 ft. wide and 13 ft. high, the inlets being 7 ft. 6 ins. wide and 10 ft. high.

Circular air-shafts, 5 ft. in diameter, are brought to the surface in square pillars, 8 x 8 ft., and closed at the top by means of gratings.

Leveling culverts, 6 x 6 ft., connected with the main culverts, are provided in each lock, and constructed with double cloughs, one of which is worked by hydraulic, and the other by hand power.

The outlets of the culverts were moulded with deals, as in the main culverts, the sills, jambs and head for the cloughs having been set previously.

An iron-lined culvert, 5 ft. in diameter, for gas and water pipes, is laid under the entrances, and is connected with the surface, at its ends and on the island, by shafts of the same diameter which pass through the pipe trenches at the top of the walls.

Checks are formed in the gate recesses and side-walls for sheave chambers, gate chains, trucks and spears.

In the top of the walls, 2 ft. 6 ins. from the face line, a trench, 4 ft. 6 ins. wide and 5 ft. high, with arched roof 3 ft. thick, is formed for hydraulic pipes, gas and water mains, etc., the pipes being laid on a benching, 3 ft. 6 ins. wide, raised 1 ft. above the floor. Manholes are placed in certain positions, and openings left for hydrants, etc.

Cast-iron curbs and covers are provided at all machinery pits, air-shafts, clough-pits, etc. Lamp-posts, mooring-posts, mushrooms,

guard-posts and chains are also provided, and the roadways adjoining the retaining walls are to be paved with granite setts.

In front of and connected with the river portion of the new walls, there is an apron, 30 ft. wide and 5 ft. thick, with a stop sunk into the rock, 6 ft. wide and 5 ft. deep, at the outer edge.

In the east wall the concrete was hand-mixed, the gravel being discharged at the northwest corner of the Toxteth Dock, whence it was conveyed in wagons to the mixing stages.

In the west wall the concrete was machine-mixed, the gravel being discharged at the river wall and conveyed in wagons to the required positions.

All concrete consists of approved aggregates of gravel, broken bricks, or stones, with a proper proportion of sand, mixed with Portland cement of the best quality, as follows: 8 to 1, 6 to 1, and 4 to 1 concrete consisting of 8 parts, 6 parts and 4 parts, respectively, of aggregates, as described, to one part of Portland cement by volume.

"Plums" were placed in the body of the concrete, and inserted so that all parts of each stone were well surrounded by concrete, no stone coming nearer to the surface of the wall that 1 ft. "Plums" were set in the top layers of concrete while it was moist, and were placed so as to project into the next layer to form a bond.

The bulk of the "plums" was not included in the proportion of aggregates above mentioned, and all stones used as "plums" were of a specially hard and durable character, thoroughly sound and shapely, and clean of all mortar and foreign matter.

The cement was delivered long enough before using to give ample opportunity for making the tests hereinafter described. A watertight, dry, wooden-floored cement store was provided on the site, and the cement was delivered there in lots of not less than 100 tons; the lots being kept clear and distinct from each other, and the stock not allowed to fall below a month's requirements.

All cement used was of the best quality, free from any admixture of Kentish rag, gypsum, or other foreign material, the contractor being required to supply with each cargo a signed declaration from the manufacturer to this effect.

Samples were taken from each lot, after delivery on the site, and these were subjected to the following tests:

"Each sample, on being sifted through a No. 50 wire-gauge sieve, must not leave a residue of more than 5 per cent.

"The time of setting of the cement must not be less than 3 hours nor more than 4½ hours after mixing, each sample of cement being considered set when it no longer takes an impression from a Vicat's needle having a total weight of 2½ lbs. standing vertically on the cement. Other samples gauged neat will be rammed by hand pressure into moulds, and some of the casts thus made will, within 24 hours, be immersed in water and at the expiration of 7 days from the day of moulding, exclusive of that day, will be tested. Other casts made as above will be allowed to air-dry, and at the expiration of 7 days as above will be tested.

"Each of the casts will be tested in a De Michele machine, and must be capable of sustaining a tensile strain of not less than 450 lbs. on a sectional area of 1 sq. in."

The specific gravity of the cement as delivered was not to have been less than 3.1, and no cement from any lot was used in the works until such lot had been tested and proved satisfactory.

Any cement from which samples had been taken and had failed to stand any of the tests before mentioned, or which at any time before use had given signs of being unsatisfactory, was rejected, and, unless otherwise directed by the Engineer, was removed, at the expense of the contractor, and did not form part of any subsequent delivery.

The foregoing tensile tests, as far as possible, were made within 14 days of the full delivery of each consignment, and the results of the tensile tests of quantities rejected, owing to failure to sustain the required strain, were forthwith communicated to the contractor.

The gravel was supplied by contract from an approved source, and was delivered alongside the quays. It was sea-washed, clean, and free from clay, silt and other foreign matter, fairly coarse, free from boulders and fine sand, and no soft, inferior material, no brick-powder, dust or dirt of any kind was used in the concrete.

Strong gauges were provided for the cement and gravel, or other aggregate, to ensure that the proper proportions as specified were maintained.

In mixing concrete by hand suitable platforms were laid down and the mixing was done as follows. As the gravel gauge was being filled the cement was added to it gradually so that when the gravel gauge was full, the cement gauge was empty. The gauge was then removed and the heap leveled off to a uniform thickness of not more than 1 ft. and was then mixed by casting backward and forward twice, the water being added as the mixture was being cast backward the second time.

After these operations had taken place, the concrete was sent down shoots into position, care being taken to insure that no concrete should be put in unless its component parts were thoroughly mixed and incorporated. In windy weather screens were provided to prevent loss of cement.

The water used for the concrete, and for all other purposes on the works, was obtained from the city mains. It was applied carefully to the concrete from a rose in such volume as not to wash the cement from the gravel. No concrete was allowed to stand after being mixed, but was used in the work immediately.

The concrete work, as far as possible, was carried on continuously, layer by layer, so that the whole formed one homogeneous mass, care being taken to remove all scum arising from the cement before putting on another layer.

The surfaces of all masonry or concrete, on or against which concrete was to be laid, were thoroughly cleaned and wetted immediately before concrete was laid on, and all wooden moulds or containing boards were payed with composition to prevent the concrete from adhering to them. In face work all the concrete was well worked against the moulds when moist, the surface, when finished, being perfectly smooth.

No concrete work was commenced or proceeded with during frosty weather, except in approved positions and subject to certain conditions.

The granite for the hollow quoins, sills, cloughs, copings, etc., was obtained from the Board's quarry at Kirkmabreck, Kirkcudbrightshire, N. B., being brought from the quarries by sea, in the rough, and dressed on the site.

The dimensions of the copings are within the following limits: Not less than 1 ft. 6 ins. nor more than 2 ft. 6 ins. deep and of a similar width, the sectional area at right angles to the line of coping being not less than $3\frac{3}{4}$ sq. ft. and not more than $4\frac{3}{4}$ sq. ft., and the length of any stone not less than 2 ft. The stones have a rounded nose of 6 ins. radius, the top rising $\frac{1}{4}$ in. per foot from the front draft.

Each stone was chisel-drafted 2 ins. wide on the face, top and bottom beds and joints, punched down to drafts on the face and top bed and below drafts on the bottom bed and joints.

The back of the stone was not squared to the joints, but was dressed to 3 ins. below the top bed, where backed by concrete.

One foot back from the face the stones were joggled, throughout their whole depth, so as to form, with the similar groove in the adjoining stone, a 3-in. square hole, this being run with cement and selected gravel, and finished at the surface with a granite plug.

The stones were bedded solidly on the concrete beneath, and the joints flushed up with cement mortar, grouted and neatly pointed.

Cement mortar for all works was generally composed of 1 part of Portland cement to 2 parts of clean sharp sand.

The surface of the quay, behind the granite coping, was carefully finished with a 6-in. layer of 4 to 1 concrete.

Between the outer and inner caisson-sills the rock under the floors of the locks is drained by vertical pipes, 4 ins. in diameter, filled with pebbles and placed 5 ft. apart laterally and longitudinally.

The gate-sills of the entrances are formed of 8 to 1 concrete with a surface of 6 to 1 concrete 1 ft. thick.

The gate clapping-sills are curved in plan, and are formed by granite stones, 2 ft. 6 ins. to 3 ft. 6 ins. long, 2 ft. wide, not less than 4 ft. deep, and at 5-ft. centers, with 6 to 1 concrete between them.

The sill stones and concrete are checked to receive the sill wood, which is bolted thereto.

The face and the bottom of the check are axed, the remainder of the face and the top bed having a 2-in. chisel-draft all around, and being punched below the draft. The sides and back of the stones are drafted and punched to a depth of 6 ins.

The cast-iron roller paths for the gate-trucks (see Fig. 4, Plate L) are fixed in the following manner: The concrete is carefully brought up to within 1 ft. of the general surface, pockets being left for the holding-down bolts. The segments of the roller paths are then placed in position on brick piers, with the holding-down bolts hanging from them, the space underneath the segments being filled with 4 to 1 concrete, well rammed,

The hollow quoins are of granite throughout, except the anchor blocks, which are of cast iron. The quoin stones, which were dressed to an iron template, are arranged so that every other is a full quoin stone taking in all the curve, the alternate one being a full-necked stone, but not taking in the full curve, the remaining portion of the curve being formed of concrete moulded in position.

The stones are of irregular form, but each stone has a thickness of at least 2 ft. back from the hollow, and the total net content of each

is not less than 35 cu. ft. The top and bottom beds are fine-axed 6 ins. back from the face, the remainder of the bed being drafted on the edges, and punched flush with the joint surface. The face, in large and small rounds, is fine-axed all over, the hollow being fine patent-axed. The faced sides of stones are chisel-drafted vertically, 2 ins. chisel-drafted at the edges and rough-punched 6 ins. back from the inside face. All stones are set as carefully as possible, and, after the completion of the quoins, the necks are re-dressed and made plumb and true throughout.

In the top and bottom beds, grooves are cut, so that, with the similar grooves in the adjoining stone, a 3-in. square joggle is formed at right angles to the side-walls of the entrances; small grooves, also, are provided, to form joggles 1½ ins. square, to allow of the running of grout.

The joints between the stones are formed on the face by a 4-in. strip of 7-lb. lead. Behind the lead the stones are carefully bedded in neat cement and afterward grouted.

The heel-post stones, which receive the pivot cups, are not less than 30 ft. in superficial area, nor less than 3 ft. 6 ins. deep, and are set on a level, bed-punched all over.

The top surface is chisel-drafted at the edges and plain-axed all over, the top portion being axed very fine.

The heel-post stones are set at 1 ft. 10¾ ins. below the sill level, the respective centers for the 100-ft. and 80-ft. gates being 2 ft. 4 ins. and 2 ft. 2 ins. back from the face of the walls. The necessary square sockets to receive the cup castings were cut after the stones were set. A cast-iron block, 1 ft. 7 ins. deep, to fit the head of the heel-post, forms part of each hollow quoin. This block is bolted to the granite beneath by three 2-in. lewis-bolts, and is anchored to the mass of concrete behind by four 3½-in. wrought-iron anchor rods, fitted and wedged in the anchor block with a square head, the other end passing through a large block of granite, 6 x 3 x 2 ft., and having a wrought-iron washer 1 ft. in diameter and 1 in. thick.

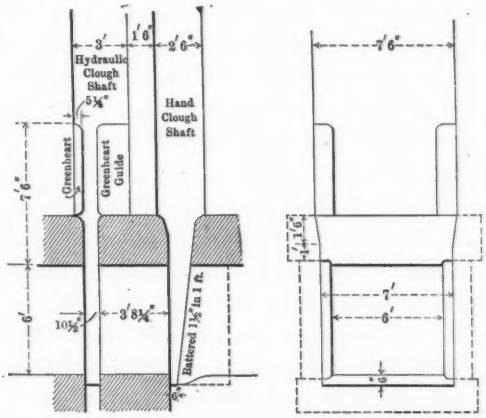
Galvanized wrought-iron collar straps, 6 x 2½ ins., are provided for each heel-post, the straps being bolted to the block by two 3¼-in. T-headed, octagonal bolts.

The square quoins, which have a bull-nose of 1 ft. radius, are formed in concrete to a level of 5 ft. above datum, from which level they are formed alternately in granite and concrete in 2-ft. layers.

The stones, which are set alternately as headers and stretchers, are not less than 5 ft. long and 3 ft. wide, having an area on bed of not less than 15 sq. ft.

Each stone is chisel-drafted 2 ins. wide on the face, the top and bottom beds being close-punched down to the drafts. Joints are chisel-drafted and punched down for 6 ins. back from the face.

All exposed surfaces of jambs, sills and heads of cloughs (see Fig. 1) are chisel-drafted and punched down below draft. The faces of grooves are polished, for 6 ins. back on the sills and jambs, and for not less than 10 ins. on the head stones.



DOUBLE CLOUGH SHAFTS FOR 6 X 6-FT. LEVELING CULVERTS.

FIG. 1.

The sills and heads are mitered to the jambs for a distance of 2 ins., with neat-cement joints.

The caisson-sills and quoins are of concrete and granite, no stone being less than 5 x 3 x 2 ft., and are dressed in a manner similar to the hollow quoins, with bearing faces fine-axed. They are set alternately as headers and stretchers, 3 ft. apart, the intervening spaces being filled with 4 to 1 concrete.

The general excavation was carried on both day and night, and proceeded simultaneously with the trenching. A sufficient distance was kept from the trenches so as not to interfere with the equilibrium of the timbering of the latter.

A Whittaker, 10-ton, steam navvy was used on this work, the wagons being lifted from the excavation to the tip levels by means of steam jennies arranged so as to serve also for erecting the lock gates.

Three lifts of 16 ft. each were taken by the steam navvy. In the first lift the material consisted principally of sand and rock dumpings; in the second, sand and gravel; and in the third, roach and rock. The bucket of the navvy had a capacity of about 1½ cu. yds. and filled

on an average two hundred and fifty 4-yd. wagons a day. For the satisfactory working of the navvy, two wagon roads, connected by jump crossings, were laid, one for empty and the other for full wagons.

Both dock and river tips were used, the former continuously: but, owing to the rise and fall of the tide, tipping could only be done at the latter during two hours before and two hours after high water. At the river, tip wagons were tipped at the rate of one every two minutes, representing about 480 cu. yds. of excavation for each tide.

The maximum quantity of excavated material sent to sea in any one week was 12 000 cu. yds.

All excavated material used for filling and for the formation of quays, roadways, etc., was deposited in horizontal layers of no greater depth than 1 ft., well watered and rammed.

Blasting operations were carried out to some extent, the explosives used being tonite and black powder.

In excavating for the island, the fault previously referred to was found to extend across the site of the south end of the island and of the outer caisson- and gate- sills of the 80-ft. entrance. In this case the excavation was carried down to 26-ft. 6 ins. below datum, from which level a trench 12 ft. wide was sunk to the full depth, the trench extending 3 ft. in front of the face line of the island and 9 ft. behind it. This trench was filled in with 8 to 1 concrete, the remaining material in the fault being undisturbed.

The foundations for the caisson- and gate-sills were laid in a similar way.

After removing the general excavation, to enable the south end of the island to be put in, a staging was erected along its center line, the height of decking being about 4 ft. below the coping level. On this were laid three lines of rails, the outside lines being used as crane roads and the center line for wagons.

The width of the decking was 40 ft., over all, and the cranes remained in position to set the coping. Concrete mixers were placed every 60 ft. along this staging, the wagon road being placed a little out of center to allow of this being done.

The gravel for concrete was discharged into side-tip wagons from vessels berthed in the Brunswick Dock; cement, "burrs" and "plums" were also brought to the required positions in wagons.

Through having no timber to relieve, the construction of the island was very rapid, two 5-ft. lifts of concrete being made per week, the moulds for the facings being supported by "soldiers" secured to the uprights of the staging.

The excavation for the northern portion of the island was then commenced, the excavated material being hand-filled into skips, lifted by the cranes on the staging, tipped into end-tip wagons, and used for filling between the walls of the southern portion of the island. The staging was removed as the filling proceeded, the uprights being sawn off flush with the concrete.

When sufficient excavation had been removed at the northern end to allow of the erection of another bay of staging, the work of excavating was stopped temporarily, the timber from the south end of the staging being used for the northern continuation.

The staging will be extended in this manner to the northern termination of the island, and, when the excavation is completed, the remainder of the island will be constructed in a manner similar to the southern portion.

After the southern portion of the island had been completed the outer gate- and caisson- sills, etc., were put in.

The gates, which had been constructed in the Board's shops, were then erected, after which the water was let in, to enable the river wall to be removed, the outer caissons to be placed, and the system of dams to be completed. (See Fig. 3, Plate L.)

By having the outer gates in position, any failure which might occur in the dams at the north end of the works would not endanger the shipping in the docks.

As much of the river wall as possible is being removed by tide-work, and the remainder by means of bucket dredgers. While the removal of this wall is in progress, the work inside the locks is, of course, stopped temporarily.

The junctions between the new and old walls at the north end of the entrances will be made and the old walls removed behind dams, the shores being relieved from the old to the new walls as the former are demolished.

It can be readily understood that, under ordinary conditions, the work might be delayed through "blows" under the dam in the Brunswick Dock while the northern portion of the work is in hand.

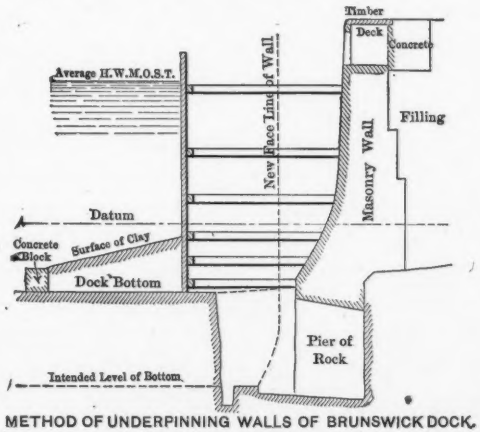
To minimize the risk of delay from this cause, the work between the dams and the wall was completed before breaking through the walls of the Brunswick Dock; safety bulkheads, founded on the new concrete, being constructed without interfering with the outer dams.

The Brunswick Dock is being deepened from 9 ft. to 21 ft. 6 ins. below datum, and the walls underpinned by adding about 12 ft. of concrete to their base, the foundation of the walls and the floor of the dock being in red sandstone of fairly good consistency and soundness.

The deepening of the floor of the dock is being carried out by dredging, and the underpinning behind flitch-dams, divided longitudinally by gussets to the wall at intervals of between 300 and 350 ft.; each section thus formed being drained by a set of chain-pumps erected upon needles supported by the quay and the dam.

The excavated material for the underpinning is removed in skips by 5-ton locomotive cranes, running upon crane roads mounted upon needles supported by the dam and the wall.

The space enclosed by the dams (see Fig. 2) having been cleared of water, a grip, about 8 ft. wide, is sunk in the rock immediately in front of the toe of the wall, to the required depth of underpinning, and on the dock side of this grip a further channel is excavated to convey drainage to the pumps.



METHOD OF UNDERPINNING WALLS OF BRUNSWICK DOCK.

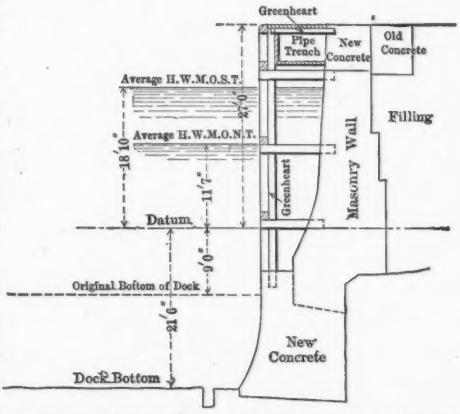
FIG. 2.

From the grip, galleries of an average width of 15 ft., are driven under the wall, on the hit-and-miss principle, so that between each gallery the wall above is supported by a pier of rock about 15 ft. wide. These galleries are filled with 8 to 1 concrete which extends outward as far as the new face line.

After the full length has been treated in this manner, those bays which were missed will be excavated and concreted.

The walls are treated in lengths of between 600 and 700 ft., this length of dam being used over again for further lengths.

Fig. 3 shows the section of the wall after the completion of the underpinning work, and the section of the timber superstructure erected upon piles stepped in the front portion of the new concrete.



SECTION OF WALL AFTER DEEPENING BRUNSWICK DOCK.
FIG. 3.

At a future date the structure will be raised in concrete from its present level of 27 ft. above datum to 30 ft. above datum, a modern shed being substituted for the present one.

The gates and gate clapping-sills are constructed of greenheart, the top of the gates being 25 ft. above datum and the bottom 20 ft. 6 ins. below datum.

The heel-posts, middle heads, and miters, are connected to the cesses by mortises and tenons, and are held together by framing bolts.

Additional strength is obtained by framing plates, on either side and at each end of the voussoirs, secured by dump-bolts.

The voussoirs are connected at the middle heads by 2-in. galvanized bolts, and hoops at the top and the bottom of the gates. There are straps at the back, and connecting timbers at the front, of the gates; the connecting timbers will also serve as fenders to protect the gates from damage when vessels are being passed through the locks. All ironwork, with the exception of straps and framing plates, is galvanized.

Each leaf is supported at the heel-post end by means of a gun metal cup-and-ball arrangement, working in a socket, and by two bevelled truck wheels, each 1 ft. 2 ins. wide and averaging 3 ft. in diameter, which travel on the iron roller paths laid on the platforms.

At the top of the heel-posts is a wrought-steel collar, 9 ins. deep, and the leaf is held up to the hollow quoin by the collar strap, in which the heel-post is free to move horizontally.

The rise of the granite sill for the 100-ft. gates at the point of miter is 16 ft. 8 ins., and that of the clapping-sill 16 ft. 10 ins. from a line connecting the centers of the hollow quoins.

Each leaf has maximum breadth of 7 ft., and is divided into three voussoirs, the radius of the back of the gate being 92 ft. and that of the clapping face 160 ft. The length along the straight from the center of the heel-post is 55 ft. 3 ins., and the diameter of the heel-post is 2 ft. 4 ins., the breadth of the miter-post at the miter being 1 ft. 8 ins. The depths of the cesses are as follows: 8 ft., 5 ft., 4 ft., 3 ft., 2 ft. 6 ins. and 1 ft. 6 ins., the spaces being 2 ft., 3 ft., 4 ft., 5 ft. 6 ins. and 7 ft., respectively, working from the bottom of the gate. The radii of the gate roller paths are 23 ft. 6 ins. and 47 ft., respectively.

The rise of the granite sill for the 80-ft. gates at the point of the miter is 13 ft. 4 ins., and that of the clapping-sill 13 ft. 6 ins. from a line connecting the centers of the hollow quoins.

Each leaf has a maximum breadth of 6 ft. 6 ins., and is divided into two voussoirs, the radius of the back of the gate being 72 ft. and that of the clapping face 130 ft. The length along the straight from the center of the heel-post is 44 ft. 6 ins., and the diameter of the heel-post is 2 ft. 2 ins., the breadth of the miter-post at the miter being 1 ft. 6 ins. The depths of the cesses are as follows: 6 ft., 4 ft. 6 ins., 3 ft. 6 ins., 2 ft. 6 ins., 1 ft. 6 ins.. 1 ft. 3 ins. and 1 ft. 6 ins., the spaces being 2 ft. 6 ins., 2 ft. 6 ins., 4 ft., 4 ft. 6 ins., 5 ft. 6 ins. and 5 ft. 9 ins., respectively, working from the bottom of the gate. The radii of the gate roller paths are 18 ft. 11 ins. and 37 ft. 9 ins., respectively.

The hydraulic apparatus for actuating the gates consists of horizontal hydraulic machines, placed in pits in the rear of the gate recesses. There are two machines to each leaf of the gates, one for opening and one for closing. The chains are carried down through chain holes, 1 ft. 3 ins. in diameter, to the sheave blocks, from which they are led to staples in the gates.

The dimensions of the machines fully provide for the stresses which may be put upon them in working the gates, with an ample margin of safety.

Machines of four types are in use, *viz.:* Opening and closing machines for the 100-ft. gates; and opening and closing machines for the 80-ft. gates.

Each machine is provided with a main ram, the easy return of which is insured by an auxiliary ram.

The following are particulars of the machines:

The main rams are provided with three pulleys on the ram head and three on the end of the cylinder, the auxiliary rams having two movable pulleys and one fixed pulley.

The machines for opening the 100-ft. gates have rams 1 ft. 7 ins. in diameter and 9 ft. stroke, and the closing machines rams of the same diameter with a stroke of 13 ft. 4 ins. The main chains in each case are $1\frac{1}{2}$-in., and the overhauling chain on the auxiliary ram $\frac{3}{4}$-in.

The machines for opening the 80-ft. gates have rams 1 ft. 5 ins. in diameter and 8 ft. stroke, and the closing machines rams of the same diameter with a stroke of 12 ft. 3 ins. The main chains in each case are $1\frac{3}{16}$-in., and the chains on the auxiliary rams $\frac{3}{4}$-in.

The auxiliary rams and cylinders are fitted to the opening and closing machinery in each case, and have a uniform diameter of 5 ins. and a stroke of 3 ft. 2 ins.

The valves are actuated by levers on the quay level, removable at pleasure, so that there is no projection above the quay level. In addition, there are stop-valves on the pressure and return pipes in the machine pits.

The hydraulic paddles of the main and the branch culverts are actuated by vertical, double-acting cylinders, the cylinders being copper-lined and the piston rods copper-covered.

The dimensions of the cylinders, pipes and valves are such that the machines are capable of lifting the paddles from their closed positions, under the full head of water, through the full lift and lowering them again to their closed positions in one minute.

The paddles are of greenheart, and are connected to the machines by wrought-iron spears dependent on a cast-iron crosshead on the piston rod. In the case of the smaller paddles, 7 x 7 ft. x 10 ins., for the 6 x 6-ft. outlets, the spears are attached to two bolts passing through the paddles from top to bottom. In the large paddles $8\frac{1}{2}$ x $11\frac{1}{2}$ x 1 ft., for the $7\frac{1}{2}$ x 10-ft. inlets, the spears are attached to a cast-iron yoke across the top of the paddle through which the building bolts also pass.

The machines for the branch culverts have 11½-in. cylinders with 6½ ft. stroke, those for the main culverts having 16½-in. cylinders with 10½ ft. stroke.

The valves are worked from the quay level by levers removable at pleasure; there are also two stop-valves in the pits, on the supply and exhaust pipes.

The hand-cloughs are actuated by a screw, suspended from a fixed bearing and worked from a bar-head. This screw passes through a brass nut in a cast-iron crosshead, from which a pair of spears is carried down to the paddle.

At the south end of the island, however, the hand-cloughs open into a gallery, in which is a crab winch traveling on rails, so that it can be brought over any clough shaft.

A chain, with bridle, is carried up from each paddle and can be attached to the winch for raising the paddle. The gallery is closed in overhead and thus presents no obstruction on the quay level. In every case, space is allowed in the clough shafts for the withdrawal of the paddles for repairs, etc., without disturbing the machinery.

The superficial areas of the hand and hydraulic paddles are similar; in cross-section, the latter are beveled 1½ ins. to the foot, commencing from a width of 6 ins. at the bottom.

At both ends of each wall, and of the island, 11-ton capstans are provided, six in all, working under a pressure of 800 lbs. per square inch at the starting valves.

The capstans have two powers, 11 tons and 4 tons, respectively, the speed of hauling being not less than 100 ft. per minute under the load of 4 tons.

The engine is connected to the capstan by a clutch, and is arranged so that one lever controls the three operations of putting into action either of the two powers, or disconnecting the engine entirely from the capstan.

The barrel of the capstan is arranged so that hand-power may be readily substituted for hydraulic power, whether or not the engine is connected with the capstan, and the capstan is fitted to receive eight handspikes. Pawls are fitted between the engine and barrel, so that when the capstan is being worked by hand, the men are not endangered.

The hydraulic engines are placed close to the capstan, and are easily accessible for cleaning, packing of glands, and repairs. The starting

valves are worked by levers from the ground level, and are removable at pleasure.

Screw stop-valves are placed on the pressure and exhaust pipes inside the machinery pits, the valves being worked by a detachable key made to suit either valve.

The machinery is designed so that, under ordinary working conditions, no part shall be strained to more than one-quarter of its breaking load.

The dams are designed to give ample strength to sustain at all times the full head of water, the outside faces being constructed and maintained in a condition to allow of vessels bearing against them without risk of injury to either the vessels or the dams.

The temporary timber dams used in connection with the work are of the flitch type, with the exception of those in the river, which are of sheet-piling.

The flitch type of dam has been adopted on the Liverpool Dock Estate as being the best, under certain conditions, for all-round purposes, its great advantage being that it can be used over again without dissection, which reduces the cost of work very considerably when new works and alterations are constantly being carried out. In addition to this, the first cost is not great, and there is generally much less leakage than with other types, especially sheet-piling dams.

Flitch dams consist of vertical timbers connected to walings, spaced to suit the pressure, and supported vertically by means of shores, with a toe of clay on the outside. The walings, generally, are 1 ft. square and 37 ft. long, the horizontal shores being spaced 12 ft. apart between centers.

The flitches are designed for a head of about 30 ft., and usually have seven walings, necessitating seven tiers of shores, the spacing of the latter being as follows: 9 ft., 7½ ft., 5 ft., 3¾ ft., 2½ ft. and 2 ft., respectively, commencing at the top of the uppermost tier and working down, the top of the lowest waling being 1 ft. 6 ins. above the bottom of the flitch.

The skin of the flitch is formed of half timbers about 6 ins. thick, the seams being caulked.

The length of the flitches is such that they can be handled readily, but the shorter the length the greater the number of shores required, as at the joints between flitches double vertical shoring is necessary.

The longest flitch used was 142 ft., and there was no difficulty in placing it; but lengths of about 120 ft. are most suitable, for, beyond this length, the flitches are likely to buckle while being placed, which may cause leakage after the dam has been pumped out.

When the ends are not at walls or the like, enclosures are made by means of gusset flitches, *i. e.* narrow flitches with walings spaced as before, one end of the gusset being shaped to suit the abutment and the other end vertical. At the vertical end the walings are cut off flush with the skin timber, and at the other end they project about 1 ft. beyond the skin. A double row of sinnet is nailed to either bearing face to make a tight joint when the dam is under pressure.

Put-holes are cut in the abutment to receive the projecting portion of the waling, and, at the other end, the gusset is supported by means of cleats bolted to the walings of the adjoining flitch in such a manner that the skin of the gusset is flush with the end of the flitch.

Paddles are provided, and, as a rule, are fixed in the gussets. As the flitches were launched, they were constructed on their flat, with the walings underneath, the lightest portion of the flitch, *i. e.*, the top, being nearest the water, so as to reduce the strain of launching.

The joints in the walings come in the center of the shores, and care was taken to insure that a number of joints did not come vertically under each other.

Each skin timber is secured to the walings by two $\frac{3}{4}$-in. bolts with their heads countersunk in the walings in order that there may be no difficulty in butting the waling end of the shores. The arrangement of the bolts along the walings is such that each tier has an equal number of bolts in its walings.

In each flitch, for slinging purposes, two whole-baulk timbers are substituted for two half timbers, one at either end of the middle half of the flitch. They are bolted at each waling, and project about 3 ft. above the top of the flitch.

At the ends of the flitch, fillings of the same width and depth as the walings, *i. e.*, 1 ft., are bolted vertically to the skin timbers between the walings in such a manner that the spaces between the walings are made good and a flush jamb formed.

To stiffen the flitch, two horizontal half timbers are run from end to end, one at the top and one at the bottom, in such a manner that their respective bolts pass through the top and bottom walings.

Occasional ring-bolts are placed along the top and bottom walings, so that rings occur on either side of the flitch.

Pig or scrap iron, or old rails, used for ballast, are placed between the two lower walings, and are secured by means of vertical deals spiked to them.

While the flitches were under construction, the work of preparing and cleansing the site for the dam was in progress. A grab dredger removed as much silt as possible, afterward a bucket dredger worked over the site to pick up anything hard and to level a bed on which the flitches were to rest; a scraping flat followed, and afterward a suction flat.

The flitches were placed by means of a floating crane, and the gusset flitches by derrick flats.

Put-holes usually formed the support for the shores at the land end, the other ends being supported by cleats bolted to the shores, the overhang of the cleats being sufficiently long for bolting to the walings, this precaution being taken to prevent the shores from floating out in case of a "blow."

The flitches are secured at the top by pennants made fast to the ring-bolts, and at the bottom by means of toggles made from old rails or bar iron bent into the form of a letter J, the long leg of the toggle being placed in a hole drilled in the rock about 6 ins. from the dam.

The bottom walings are first shored opposite the toggles, after which packings are fixed between the toggles and the flitch. The shoring is then completed, all shores placed by divers being weighted by means of pig iron or old rails spiked to either side of the shores.

Any very hollow places under the flitches were made up by means of concrete, and, when the space was small, bags of clay were placed in the angle formed by the flitch and the bottom.

Concrete blocks are placed about 18 ft. away from the face of the dam and along its entire length, in such a manner that a revetment is formed for the clay.

The blocks, which are 6 × 3 ft. and 3 ft. deep, are laid lengthwise with the dam, and the clay is placed between the dam and the concrete blocks to a height of about 8 ft. at the flitch, tailing off to the depth of the blocks.

In the case of long shores, lacings are provided, also "toms" to give vertical support to the shores.

The butts of the shores are in all cases cut square, and, in the case of diagonal shores, cleats, bevelled to suit the angles formed by the shores and the walings, are spiked to the latter.

The position of the pumps is such that the work below dock water level may be completed without their removal. Whenever possible, the pump framing is quite independent of the dams, so that, in case of accident to the latter, the pumps will not be disturbed.

After the divers had finished their shoring and the clay had been well rammed, before an attempt was made to pump out, a careful examination of all the under-water shores was made to ensure that they were all in place and that none was under too great a strain.

As regards maintenance, with a view to minimizing the dangers of "blows," soundings are taken from time to time at regular intervals along the entire length of the dam, to guard against any fretting of the clay.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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LOADINGS FOR RAILROAD BRIDGES.

An Informal Discussion at the Annual Convention, June 11th, 1903.*

SUBJECT FOR DISCUSSION:

"In view of the Increasing Weights of Rolling Stock, for what Loadings should Railroad Bridges be Designed?"

By THEOOORE COOPER, M. Am. Soc. C. E.

Mr. Cooper. THEODORE COOPER, M. Am. Soc. C. E. (by letter).—That the loads on freight cars, or the weights of engines, will continue to increase per running foot of track to an unknown or indefinite extent is, in the writer's opinion, a most erroneous assumption.

Excepting special lines of road, carrying one kind of freight between definite terminal points, as certain mine, quarry or ore roads, the interchange of traffic between the numerous lines composing the railroad system of the American Continent demands that all cars shall be able to pass freely over each line, without surpassing vertically or laterally the limiting clearances, which determine the limiting cross-section of the train, including engines and cars.

While some roads have cars in use locally which would not be accepted on other roads, it is very certain that the great interchange of freight will ultimately compel the adoption of standard cars which can pass freely over all lines.

The American Railway Association has recently adopted a standard box-car,† which, presumably, is as large as would be acceptable to all roads.

*The discussion of this subject, on which no formal paper was presented, is continued from the August, 1903, *Proceedings*.

† *Railroad Gazette*, July 3d, 1903.

Mr. Cooper.

It has the following inside dimensions: 8 ft. high, 8 ft. 6 ins. wide, and 36 ft. long.

The inside cross-section of this car, 68 sq. ft., when reduced to the length of track covered, distance between bumpers, gives about 65 sq. ft. as the maximum storage capacity per linear foot of track.

By reference to the writer's paper,* "Train Loadings for Railroad Bridges," in Table No. 3, it will be seen that this car could be completely filled with any kind of freight, excepting minerals and metals, without exceeding 4 000 lbs. of freight per linear foot of track. Practically, it would be impossible to fill this car completely.

If we allow (as would appear liberal) 1 000 lbs. per foot of track for the weight of the car, the maximum load per foot for fully 90% of the freight handled on our roads could not exceed 5 000 lbs.

Of the remaining 10% (excluding special ore-carrying lines) the larger proportion consisting of machinery, structural work, manufactured articles, etc., could not be stored within the limiting cross-section so as to exceed the above maximum.

Such cars, with this maximum loading, would weigh 190 000 lbs., which, with four axles, would give 47 500 lbs. per axle, or, with six axles, 31 667 lbs. per axle.

The self-dumping 100 000-lb. coal car has 36 500 lbs. per axle and 4 300 lbs. per foot of track.

As such loads on 33-in. wheels, when the wheels once become worn or roughened, would be far more trying to the track than the heavier driving-wheel loads, owing to the larger diameter and better care, it is certain that there must be a limit to such loads, as determined by longer experience.

Considering the small percentage of the freight which could be stored in the limiting cross-section so as to give greater loads per foot of track than 5 000 lbs., and the impossibility of keeping such cars in continuous circulation with full loads, except upon the specially excluded ore roads, their introduction upon the general railroad system is improbable.

It would seem to be justifiable, therefore, to assume that there is an upper limit to the freight load per running foot of track, and that 5 000 lbs. covers the limitation, unless it is assumed that the existing railroads will increase their present clearances, a tremendous undertaking in time and money.

Engines, also, must be limited in size and weight by the limiting cross-section of the roads, if not by the permissible axle loads.

With the limitation of the driving-wheel base, increased weight on the drivers demands more space for the greater boilers, cylinders, grate surface and running gear.

In *The Railroad Gazette* of October 27th, 1899, there is a theoretical

* *Transactions*, Am. Soc. C. E., Vol. XXXI, pp. 174, 183.

Mr. Cooper. examination as to the heaviest engine which could be built, under certain assumptions and with the usually accepted road clearances. Whether the conclusions of that writer are exact or not, it is interesting and instructive as showing the influence of the allowed cross-section of a road upon the maximum possible engine, and indicates that, under present restrictions, we have about reached, in existing engines, the maximum possible. His maximum requires five coupled driving axles with a fixed wheel-base.

For further increase in the weight and power of the motor, we must either look forward to the possibility of electricity or to a series of combined motors with articulated wheel-bases.

It is reported that the Baltimore and Ohio Railroad has now under construction an engine with 285 000 lbs. on six driving axles with an articulated wheel-base, the three forward and three rear drivers each having an individual wheel-base of 10 ft. and a total wheel-base of 30 ft. 6 ins.

Such an engine, however, would not produce any greater stresses on bridges than the typical consolidation engines with the same load per axle.

It would appear to the writer, therefore, that maintenance-of-way conditions, weights on axles and car wheels, and existing clearances, all indicate that we are at or close to the maximum train loadings, under the present construction and limitations of our railroads.

On October 9th, 1899, the writer recommended the adoption of his train loading, *E* 50, by one of our important roads, as being, in his opinion, sufficient to cover all future load developments, when combined with the conservative unit strains now in general use; strains, which in the past have been very greatly exceeded, on nearly all roads, without risk or detriment, by the heretofore constantly increasing loads imposed.

It is not apparent, at present, why this opinion should be revised.

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IMPERVIOUS CONCRETE.

An Informal Discussion at the Annual Convention, June 11th, 1903.*

SUBJECT FOR DISCUSSION:

"Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

BY THEODORE BELZNER, Jun. Am. Soc. C. E.

THEODORE BELZNER, Jun. Am. Soc. C. E. (by letter).—The writer has read with much interest the discussions on "Impervious Concrete," and recalls having seen specifications of water-proofing calling for two layers of felt in ground that is quite dry, and where there is water pressure against the masonry equal to 12 ft. there should be used not less than six layers of felt. When the water pressure is less than 12 ft., or where the ground is damp, from three to six layers should be used, such being left to the discretion of the engineer in charge. Mr. Belzner.

The writer firmly believes that concrete can be made impervious to water, but not at a reasonable cost, on account of the expense of the proper application of the materials.

Some time ago the writer examined a jack-arch where moisture appeared, and after cutting out the concrete, about 18 ins. square and 12 ins. thick, the water-proofing behind it was found to be punctured and had bulged about 8 ins., caused by the pressure of the surface water. The water-proof paper was removed and replaced, and the section of the arch replaced with brick dipped in hot asphalt, and since then no leaks have occurred.

* The discusssion of this subject, on which no formal paper as presented, is continued from the August, 1903, *Proceedings*.

Mr. Belzner. The writer has had some experience in locating leaks in steel-concrete construction, and in jack- and roof- arches, and has traced to their source leaks caused by surface water, and in some cases, has found the puncture to be from 5 to 20 ft., or more, from where the dampness appeared upon the surface.

When moisture appears on a wall it does not necessarily indicate that the leak is directly behind it; the source may be a great distance from where the sweat appears.

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AN EXPERIMENTAL STUDY OF THE RESISTANCES TO THE FLOW OF WATER IN PIPES.

Discussion.*

By Messrs. A. Flamant, Hiram F. Mills, Edgar C. Thrupp and Allen Hazen.

Mr. Flamant.

A. Flamant, Esq.† (by letter).—This paper is exceedingly interesting. For brass pipes of small diameter, the experiments confirm the law of variation of resistance proportionate to the power, 1.75, of the mean velocity, the law which the writer applied in 1892‡ to pipes of cast iron in ordinary use, and for which he has drawn up numerical tables, etc.

But, on the other hand, the authors find, for galvanized pipes, a variation proportionate to the power, 1.90 (about) of the velocity; which seems to indicate that the exponent of V varies with the condition of the interior surface of the pipes.

From this point of view, it would be interesting to make new experiments with pipes of different materials, such as glass, earthenware, wood, wrought iron, cast iron; or, perhaps, more simply, to ascertain the effect of an interior coating of paint, tar or some similar material. Perhaps, by making a sufficient number of experiments, comparative among themselves, one could formulate a definition or a

* This discussion (of the paper by Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E., printed in *Proceedings* for May, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Communications on this subject received prior to October 23d, 1903, will be published subsequently.

† *Ingénieur des Ponts et Chaussées*.

‡ *Annales des Ponts et Chaussées*, September, 1892.

Mr. Flamant. more exact indication of what is called the rugosity, and which, according to the authors, seems to influence not only the coefficient, m, of their formula, but also the exponent, n.

As to the effect of temperature, the writer believes that it is especially appreciable because the diameters of the pipes experimented upon are small. This effect ought to diminish rapidly, as the diameter increases, and, for the usual diameters, should become entirely negligible. This, at least, seems to have been established by M. V. Fournié, in an article* from which the conclusions are quoted by the writer on page 144 of the second edition of his work on "Hydraulics" (Paris, 1900).

Although it was known, the confirmation of the increase of flow, with the temperature, for pipes of small diameter, is interesting. The writer is surprised, therefore, that this variation has been found so nearly the same for the very small diameters (as of Pipes *XIV*, *XV* and *XVI*), as for the larger (as Pipes *II*, *III* and *IV*). It would be useful to ascertain whether the same effect would continue to appear in pipes of the usual diameter, 20 cm. to 1 m., for example.

On the whole, the work of Messrs. Saph and Schoder has brought out a valuable collection of precise, experimental facts which will be very useful for the solution of this difficult problem, and which seem to be especially of a nature to solve new questions of detail, which makes it desirable that these capable observers should continue their researches.

Mr. Mills. Hiram F. Mills, Esq. (by letter).—The writer has examined with a good deal of care most of the experimental results presented by Messrs. Saph and Schoder, and must express his cordial appreciation of the care and skill with which this series of experiments has been planned and executed. The educational institution that prepares men for and fosters such work is to be highly commended.

The data furnished by the observations are a valuable addition to the science of hydraulics, and worthy of the careful study of its students. They give a distinct addition to our knowledge of the effect of temperature upon the flow of water in pipes, and it is desirable that still further knowledge be obtained upon this subject, for, while these experiments upon small smooth pipes bring out the effect in a very marked degree, the effect is not to be neglected in larger pipes used in water-works.

The most interesting single series of experiments, because it gives the slopes for both high and low temperatures through the greatest range of velocities, is that upon the smallest brass pipe, which is about $\frac{1}{10}$ in. in diameter. These experiments illustrate conditions which are met in hydraulic experiments with larger pipes in a much smaller degree, and serve to explain some apparent anomalies therein.

* *Annales des Ponts et Chaussées*, 1898, 3e Trimestre.

Mr. Mills.

With temperatures of water near 70° Fahr., the slope varies nearly with the first power of the velocity, being contained between $S = 0.129\ V$ and $S = 0.138\ V$, for all velocities given up to $V = 2.309$ ft. per second. Above this velocity the slope increases much more rapidly, changing from $V = 2.559$ with $S = 0.3736$ per foot to $V = 2.917$ with $S = 0.6061$ per foot, which is an increase of slope with the 3.69 power of the velocity. Upon reaching a velocity of 3.3 ft. per second, the slopes come into line with those of higher velocities which vary with a power of the velocity somewhat less than the second power, being, with this very smooth pipe, near the 1.75 power. With small velocities, with slope increasing directly with the velocity, the water having the lower temperature has the greater slope, but, during the rapid increase that follows, the warmer water, being less viscous and more mobile, makes this change at smaller velocities than the colder water, and the slope for 75° is greater than the slope for 70°, and both become greater than that for 38.5 degrees.

With the temperature of the water at 38.5°, the slope increases with the first power of the velocity at a much more rapid rate than with temperature of 70°, and continues in this condition through much higher velocities. Its slope is expressed by $S = 0.212\ V$, or 52% greater than water at 70°, and continues at this rate until it reaches a velocity of about 3.5 ft. per second. At a velocity of about 2.9 ft. the warmer water, in its rapid increase of slope, reaches the slope of the colder water and soon exceeds it, while the colder water, keeping on with its steady rise, gets to have a slope 14% less than the slope of water at 70° at the same velocity.

At a velocity of about 3.5 ft. the water at 38.5° begins to change its condition, and its slope increases with about the 2.5 power of its velocity and equals the slope of water at 70° at a velocity of 4.5 ft. per second, then rises above it, and, at 5.4 ft. velocity, reaches its permanent condition of flow for higher velocities, and continues with about 10% more slope than the water at 70° temperature.

It is interesting to compare this result with experiments which the writer made, in 1875 and following years, upon the flow of water through a cast-iron, tar-coated pipe, 1 ft. in diameter, which showed about 4% increase in slope with decrease in temperature through the same range.

But, in order to understand the effect of temperature, and study its laws, the writer thinks it necessary to divide the slope into its two parts, one depending upon shocks and mass, and varying with the square of the velocity; and the other depending upon cohesion and adhesion, and varying with the first power of the velocity.

Making such division, as well as he may from the experiments, the writer finds that, in the small brass pipe, the part of the slope varying with the square of the velocity increases about 8% with the decrease

Mr. Mills. in temperature, and the part varying with the first power increases about 17%, while in the large pipe having a diameter 120 times as great, the part varying with the square of the velocity increased not more than 2%, and the part varying with the first power of the velocity increased as much as 29% with the decrease in temperature from 70 to 38.5 degrees. Much more may be deduced from these experiments to show that the principal effect of temperature is upon that resistance to motion due to cohesion and adhesion which varies with the first power of the velocity.

Mr. Thrupp. EDGAR C. THRUPP, Assoc. M. Inst. C. E. (by letter).—The writer shares the authors' desire to abolish the term, $\frac{V^2}{2g}$, from pipe-discharge formulas, although their illustration of water being forced through a pipe by compressed air is not a very happy argument against it. The faith of students will be severely strained if they are taught to believe in the theory when abundance of experimental evidence exists showing the index of V to vary from 1 to 4. A more satisfactory view is to regard a formula for the flow in pipes as a statement of the conditions under which the frictional resistance equals the moving force. Gravity undoubtedly determines the moving force, but has nothing to do with the frictional resistance. Gravity sets the water in motion and increases its velocity until its force is balanced by friction, but this is a very different thing from determining the velocity as proportional to $\frac{V^2}{2g}$.

The writer does not agree with the authors' assumption of the continuity of their law of critical velocities $\left(V = \frac{0.088}{d^{0.784}}\right)$ for pipes of larger diameter, as he knows from his own experiments that there is a rapid divergence from such a law when the hydraulic radius exceeds $1\frac{1}{2}$ ins., and that the critical velocity then increases with the hydraulic radius. The question of the critical velocity may be of little importance as regards the water supply of towns, but it will be found to be a matter of very great importance in irrigation and estuary or tidal-river hydraulics, particularly in relation to silt carrying and scouring, and also in connection with the resistance of high-speed ships.

The authors seem to be unduly confident in their assumption that the index of R may be taken as constant through a wide range in values of R, in the formula

$$V = 279\, S^{0.57}\, R^{0.71} \pm 4 \text{ per cent.}$$

The writer investigated this point very fully in 1887, and arrived at the conclusion that for small values of R the index must be greater than for large values, and gave an empirical method of expressing the variation.* The authors' experiments confirm the writer's conclusion

* *Transactions* of the Society of Engineers, 1887.

because they show an index of 0.71 for small, smooth pipes, and this is certainly too large for pipes more than 6 ins. in diameter. Mr. Thrupp.

The region covered by the experiments has now been well explored, and there is not much to be learned by further experiments on small pipes, but if some of the technical colleges having hydraulic experiment facilities were to use them for research on the critical velocity phenomena in relation to R and V, and the hydraulic gradient in open channels with $R = 2$ ins. and upward, much information of practical and scientific value would be brought to light.

ALLEN HAZEN, M. Am. Soc. C. E. (by letter).—The paper records a most interesting investigation of the flow of water in small pipes. Mr. Hazen.

There seem to be two elements in the friction of water in small pipes: One depends upon the viscosity of the water, and is of controlling importance in capillary tubes; the other seems to depend more upon the kinetic energy required to produce the motion of the water in whirls and eddies and other motions, and this element is of controlling importance in larger pipes. It might naturally be supposed that each of these elements of friction would be present in all cases, but in varying relative amounts. Darcy's formula for the flow of water in pipes is in a form corresponding to this idea; that is to say, two terms are used, one, varying with the first power of the velocity, which is the power which applies in capillary tubes; and a second, varying with the square of the velocity, which is the power found to apply to the flow of water through very rough and crooked channels of large size.

The experiments of the authors do not indicate such a gradual transition from one condition of the flow to the other. They indicate, rather, that the flow of water in tubes, up to a certain point, called the critical velocity, follows accurately the flow of water in capillary tubes, and without change in the exponents and coefficients; and that from a point slightly above this critical velocity the laws of flow are the same as for much larger pipes, and that the same exponents and coefficients apply.

The writer's experience with the flow of water in gravels had led him to anticipate a more gradual change than that shown by the authors. For a gravel at low velocities the friction varies with the first power of the velocity, and, as the velocity increases, the divergence from this law is at first slight and gradually increases, until finally, at much higher velocities, it varies with the square of the velocity.

The experiments of the authors are most useful in throwing light upon this point. The change from one state of flow to the other may be compared to the flow of water through a vertical orifice. With water slowly rising behind it, the orifice first acts as a weir. It follows precisely the law of discharge over a weir until the water hits the top of the orifice. Thereupon the flow is at once retarded, and it com-

Mr. Hazen. mences to act as an orifice, and follows perfectly the law of discharge through an orifice. There is no intermediate ground. It acts either as a weir or as an orifice. But there is a certain range in which it will act as an orifice, if it happens to be started that way, or as a weir, if it happens to be started that way, and it will not change from one to the other except by some outside influence, and it may be somewhat the same with small pipes.

The authors have discussed at length the formula for the flow of water in brass pipes above the critical velocity. The experiments also furnish some data for computing the flow below this velocity, but this matter is not discussed in the paper. The writer has taken the results of those of the experiments which seem to be clearly below the critical velocity, and has compared them with the formula for the flow of water in capillary tubes, which is taken to be

$$v = c\, d^2 \left(\frac{t + 10}{60}\right);$$

t being the temperature, and d the diameter, in inches.

The factor $\left(\frac{t + 10}{60}\right)$ is one which was deduced from experiments at Lawrence to represent the flow of water, at different temperatures, through capillary tubes. It also represents the relative rates at which water passes through sand, and at which silt settles through quiet water. This term is more convenient for practical use than the conventional factor of Poiseuille, and is sufficiently accurate. It seems to be based on one of the primary physical properties of water, and is applicable directly, and with considerable accuracy, to all the phenomena which depend upon the viscosity of water.

In Table No. 10, the writer has stated the experimental results, as taken from the authors' tables, and has computed the value of c, first, without using the temperature factor, and afterward, the temperature factor appears, and finally, the value of c, corrected for the temperature factor.

The changes in temperature in these experiments were too slight to throw much light on the application of the temperature factor. Only in the case of the smallest pipe, No. *XVI*, was there a considerable range in the temperature. This series indicates a variation in flow with change in temperature amounting to about 79% of that computed in the formula stated above. The writer thinks there can be no question that the temperature factor will apply much more closely than this to small pipe. Possibly the smaller variation with this pipe indicates some change in the condition of the pipe between the two series of experiments, or it may indicate the beginning of a gradual change in the form of flow and a slight tendency to the condition with higher velocities, where the influence of temperature is comparatively slight.

TABLE No. 10.

Mr. Hazen.

No. of experiment.	No. of pipe.	Diameter of pipe, in inches.	Slope, in feet per hundred.	Velocity, in feet per second.	Value of c, temperature factor omitted.	Temperature.	Reciprocal of temperature factor.	Value of c, corrected for temperature.
201	*VII*	0.631	0.087	0.218	630	71.8	0.732	462
200		0.631	0.187	0.471	630	71.3	0.739	465
292	*IX*	0.376	0.125	0.111	628	69.0	0.760	477
291		0.376	0.320	0.291	641	69.0	0.760	487
290		0.376	0.590	0.541	648	68.8	0.761	493
289		0.376	0.955	0.849	628	68.6	0.765	479
298	*XIII*	0.221	0.870	0.267	628	62.4	0 829	520
297		0.221	1.860	0.540	592	62.1	0.832	493
296		0.221	3.140	0.898	582	62.0	0.833	485
294		0.221	4.470	1.270	580	61.5	0.839	487
98	*XV*	0.151	2.001	0.300	658	70.0	0.750	493
97		0.151	8.623	1.248	634	70.0	0.750	475
230		0.151	9.380	1.362	640	73.1	0.721	462
258		0.151	11.470	1.767	675	72.9	0.723	489
114	*XVI*	0.107	5.910	0.451	665	70.9	0.740	492
102		0.107	7.804	0.602	672	69.5	0.755	507
113		0.107	11.710	0.911	680	70.4	0.745	508
101		0.107	18.290	1.378	655	69.0	0.758	497
108		0.107	23.600	1.790	660	71.9	0.732	483
100		0.107	28.590	2.074	635	68.0	0.768	488
112		0.107	31.930	2.309	630	70.2	0.748	472
221		0.107	8.970	0.730	710	75.2	0.704	500
220		0.107	19.890	1.614	708	75.1	0.703	498
442	*XVI*	0.107	7.200	0.387	470	38.3	1.240	584
441		0.107	19.000	0.958	440	38.4	1.240	545
440		0.107	33.300	1.635	428	38.5	1.240	531
439		0.107	65.800	3.142	416	38.5	1.240	515

It is interesting here to note that the experiments of Hagen, as quoted by the authors, seem to correspond very closely with the above-mentioned temperature factor. Thus, taking the smaller pipe, 0.00924 ft. in diameter, or approximately 0.11 in., at a slope of 1 in 10, the temperatures, velocities, etc., are as given in Table No. 11.

TABLE No. 11.

Temperature.	Velocity, scaled from plotting.	Reciprocal of temperature factor.	Product.
41	0.451	1.176	530
47.3	0.506	1.045	530
59	0.547	0.986	540
54.7	0.581	0.926	540
66	0.675	0.790	533
75	0.770	0.705	544
80	0.832	0.667	555
88	0.900	0.611	551
100	0.955	0.545	552
110	1.09	0.500	545

The product is constant, and the agreement is as close as the velocities can be scaled from the plotting.

Mr. Hazen. The experiments of the authors indicate that c, in the above-mentioned formula, ranges from 462 to 584, averaging about 495. The experiments of Hagen show a value about 10% lower. The experiments thus serve to establish a coefficient in the formula for the flow of water in small pipes below the critical velocity, and the data are most useful in this direction.

An interesting deduction is that the critical velocity in a pipe is at a point where the flows computed by the formula for the flow of water in larger pipes and by the formula for the flow in capillary tubes are equal, and that in all other cases the flow follows the formula which gives the lowest velocity for a given slope.

The effect of temperature upon the flow of water in small pipes above the critical velocity is most interesting. The effect of temperature seems to be less than one-quarter of what it is below the critical velocity. It is, nevertheless, large enough to be an important element. The question may be raised as to whether temperature exerts a corresponding influence in much larger pipes, or whether the effect noted in these experiments represents the beginning of a gradual change toward the capillary condition. The experiments themselves give no indication of this, as the effect of temperature seems to be quite as great with the larger tubes as with the smaller ones, but, if it should prove to be otherwise, it would affect materially some of the deductions of the authors.

The general form of formula proposed, although very similar to some of the formulas which have been used, presents some interesting points. According to the authors, in the general formula,

$$v = c\,(r^x\, s^y),$$

x and y are proportional to each other, and x is always 1.25 of y. This conclusion is diametrically opposed to that of Tutton,* whose analyses led him to the conclusion that, as x increases, y decreases, and that the sum of the two exponents is a constant, namely 1.17.

It is comparatively easy to determine the value of y in particular cases. It involves passing water through a pipe at different velocities and noting the heads required. This is an experiment for which there are many opportunities, and sufficient data are available to give a very good idea of the value of this exponent for various conditions. It is much more difficult to find the value of x.

The authors have a very simple method of computing x when y is known. Tutton's method is equally easy, but, unfortunately, leads to very different results. It has seemed to the writer that the most accurate value for x could be secured by comparing the results obtained for very small and very large pipes. Of course, it is impossible to secure very large pipes with precisely the same kind of interior surface as obtained in very small pipes, but it seems safer to compare the results

* *Journal of the Association of Engineering Societies*, Vol. XXIII, p. 151 (1889).

Mr. Hazen.

obtained from very large and very small pipes, even though their interior surfaces do differ somewhat in character, than to take the indications of experiments more closely comparable, but covering a shorter range. These experiments afford some admirable material for use in this way, but it may be questioned whether the method of computation is the best that could be used.

The proposition that the friction varies inversely as the 1.25 power of the diameter is derived from the plotting reproduced in Plate XLI.* This plotting gives the values of m, in comparison with the pipe diameters, in inches. An examination of the formula used by the authors shows that this value of m is the slope in feet per thousand when the velocity is 1.00. This value is usually not the result of direct observation, but is computed from observations taken at much higher velocities.

The exponents shown by the authors, in connection with the various experiments, indicate the rate at which the slope increases with increase in velocity. At that end of the plotting which shows the smallest pipe, these exponents average, as stated by the authors, about 1.75. At the opposite end of the plotting the exponents average much higher than this. Beginning at the upper end and keeping near the lower line, indicating smooth pipe, there are positions marked: Benzenberg, 2.15; FitzGerald, 1.929; Stearns, 1.892; Williams, Hubbell & Fenkell, 1.765; Coffin, 1.726; Williams, Hubbell & Fenkell, 1.858; Hamilton Smith, 1.94; Adams, 1.74; Darcy, 2.00; Williams, Hubbell & Fenkell, 1.779; Darcy, 1.807. The average of these exponents is 1.87.

The fact that the exponents are higher at this end of the line than at the other indicates that if a comparison were made at a higher velocity than that assumed, which is 1 ft. per second, the slopes would be increased more for the large diameters than for the smaller ones; in other words, the exponent in the reciprocal ratio would be reduced.

Plotting the results of the experiments relied upon by the authors for a velocity of 3 ft. per second, and using the actual experimental values for the velocities, or values reduced from the experiments nearest to them, it is found that they diverge much more from the line for the authors' experiments for brass pipe than is the case for the plotting of the values of m. It is, unfortunately, a fact that probably none of the large pipe had as smooth surfaces as the brass pipe used by the authors, and some allowance must be made for this fact in the comparisons; and, while the line drawn as a general average would be a matter of individual judgment, the writer would hardly give it an inclination greater than that corresponding to an exponent of 1.20. If the matter were carried further, the exponent would probably be lower. Further, if the temperature effect should be

* *Proceedings*, Am. Soc. C. E., for May, 1903.

Mr. Hazen. found to be different in large and small pipes, the value would vary with the temperature.

For these reasons, care must be taken in extending the values found for very small pipes to large sizes, and it would be better to go slowly in accepting a constant ratio between the exponents of the general formula.

The experiments are of no less value because of this. A critical examination of extremes may lead to a more accurate understanding of intermediate values, and in this case the large number of experiments exceeds anything available for the larger sizes of pipe for which accurate computations are most often desired.

It seems that every discussion of this subject only makes it clearer that no one formula can be made to apply to all the conditions that there are, and, fortunately, such a formula is not necessary for practical purposes. The Chezy formula is most useful, notwithstanding its wide divergences from ordinary conditions. It is easy to devise exponental formulas to represent the average of particular experiments, but the multiplication of formulas is confusing. The writer has felt, however, that a formula with exponents representing more nearly than those of the Chezy formula the average of all-round water-works practice, with such values of c as should be found by experience, would be serviceable, particularly if an easy means of solution of problems by it were provided. This idea was taken up with Professor Gardner S. Williams, M. Am. Soc. C. E., and the formula

$$v = c\, r^{0.63}\, s^{0.54}\, 0.001\, (^{-0.04})$$

was adopted, not as representing clean pipe or dirty pipe, or large pipe or small pipe, particularly, but simply as an approximation to the conditions most commonly met, particularly in water-works practice. To solve this formula, a slide rule was designed, which was first constructed in a home-made way, and afterward more accurately by an instrument maker. This rule allows a very rapid solution of common hydraulic problems by the formula, and the regularity in the values of c found applicable with it indicates a sufficiently close approximation to accuracy in the exponents selected, for most practical purposes.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SEWAGE PURIFICATION.

An Informal Discussion at the Annual Convention, June 10th, 1903.*

SUBJECT FOR DISCUSSION:

"Sewage Purification."

By MESSRS. RUDOLPH HERING and GEORGE W. RAFTER.

RUDOLPH HERING, M. Am. Soc. C. E. (by letter).—The writer's compulsory absence prevents him from opening this discussion in person, as he had intended, namely, to outline the entire subject in its essential parts, dwelling upon those methods which are now more or less on trial and concerning which there is a lack of enough experience to eliminate all differences of opinion. Instead, he sends the following brief remarks: Mr. Hering.

This subject stands to-day, in a totally different light from what it did less than twenty-five years ago. A complete purification of sewage now resolves itself into the necessity of establishing the best conditions for the most suitable bacterial life to become most effective, because only in recent years have we recognized this minute life to be the essential feature in the process.

Bacteria may be active in flowing, or in large bodies of comparatively quiet, water. To get the desired effect, the bacteria contained

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV, p. 71.)

Communications on this subject received prior to October 23d, 1903, will be published subsequently.

Mr. Hering. in the sewage itself, its proper dilution, accomplished in an inoffensive manner, is therefore one of the important questions, and it is not yet completely answered.

The purifying bacteria may also be active in porous soil, notably in sand, and in imitation of Nature's production of spring water, the result may be completely satisfactory under suitable conditions, which are now fairly well understood.

Under still other conditions, a different class of bacteria, also contained in sewage, is brought into service, or the same bacteria may be brought to act under modified conditions, and, with the aid of the liquefying process of putrefaction caused by them, we may get rid of much of the suspended matter, which is the most troublesome element in all phases of sewage purification. But such aid only partially solves the problem. Bacteria must again be set to work to convert the liquid sewage finally into mineral and inoffensive solutions. In order to gain this end, a number of practical ways of accomplishing these different processes are now in use

Numerous local conditions have been the cause of a variety of solutions, some of which are still on trial and await further investigations and study from actual experience on a large scale. In America and in Europe this experience is now being gathered, and a general discussion of the recent results gained should be instructive and valuable.

Mr. Rafter. GEORGE W. RAFTER, M. Am. Soc. C. E. (by letter).—Sewage disposal has always been a simple enough matter to the non-technical people who mostly control the affairs of municipalities, but to those charged with its administration, it has been, and still continues to be, exceedingly complex. The latter class are conservative in estimates and statements, while the former are positive that they, at any rate, have struck the final solution.

When the matter is examined historically, it is found that sewage disposal, pendulum-like, has swung back and forth between certain extremes. From fifty to sixty years ago the sewage nuisance had so far forced itself upon public attention that a considerable number of works were constructed in England, and in the report of Henry Austin, "On the Means of Deodorizing and Utilizing the Sewage of Towns," published in 1857, a general *résumé* of the subject is given. At that time, chemical precipitation was coming into use, and extravagant notions of the value of the manure to be obtained were indulged in. It is unnecessary to state that none of these methods has justified the hopes of its inventors. A great many patents were taken out for various chemical processes, from about 1835 to 1860 or 1870, but the majority of these patents were so impractical as never to go into operation. Indeed, sewage disposal, owing perhaps to its complex nature, is not properly subject to patents. The useful developments,

thus far, have been mostly the work of scientific men, and ordinary inventors have scarcely contributed anything thereto, nor are they likely to, because the complexity of the operations is such as to be beyond them. Mr. Rafter.

The separation of the solid matters in suspension by sedimentation, straining or filtration, however, is an interesting process, which was tried in England about the year 1850, and which, from its developing on lines quite similar to what is now known as the septic process, may be considered a little at length. Mr. Austin describes the works at Cheltenham, England, for what he calls a mechanical process for separating the solid matter of sewage, as follows:

"The building is divided longitudinally, forming below ground two sets of reservoirs or tanks, which are employed alternately. The sewage passes through vertical filters in the upper and lower tanks, whereby the great bulk of the matters in suspension is separated and retained. These filters are 5 ft. deep and 2 ft. thick, and consist of coarse gravel inclosed within 2-in. perforated boards, these being protected with basket work to prevent clogging.

"The heavier matters of the sewage deposit themselves at the bottom of the tanks, but a large proportion of the solid forms itself into a floating body, and accumulates to about 18 ins. thick on the surface. The liquid is conveyed from the angular filters in the upper tanks by a line of pipes in each division.

"A weir, or rather division, in the third or lining tank, causes the water, then partially clear, to flow through a channel at each end, during its passage through which a certain proportion of cream of lime, mixed on the floor above, falls into it, and occasions a further precipitation to take place. The effluent water then passes through another filter with gravel finer than before, and then through a third, finer still, to the outfall.

"When either reservoir contains a certain amount of solid matter, the flow of sewage is cut off and turned into the other. This takes place about every eight weeks, and the filtering medium of gravel is removed at the same time and washed. The contents of the tanks which are in a state of 'slush' are then hoisted in buckets through the trap lids on to the floor above, and wheeled out and mixed with the scavenger's refuse of the town, the ashes, street sweepings, etc. These are brought to the yard, and a kind of embanked reservoir is formed of them immediately outside the building, and as the semi-solid sewage is wheeled into the midst, the dry refuse outside is turned on to it. The liquid is at once absorbed, and after being turned over and thoroughly intermixed, the solid mass is fit for immediate removal and use.

"The ashes and dry refuse of the town are said to be just sufficient for the purpose. They absorb about two-thirds of their bulk of sewage; that is to say, one cubic yard of the ashes, etc., and two-thirds of a cubic yard of the semi-fluid sewage, make only one cubic yard of solid manure."

The foregoing quotation is especially interesting as indicating that Mr. Austin observed an operation in the Cheltenham tanks exactly as is now known to exist in a septic tank; that is, the heavier matters deposit themselves at the bottom, while a considerable portion of the

Mr. Rafter. solids forms itself into a floating body, accumulating to the thickness of about 18 ins., on the surface. In view of this fact, it seems fair to say that in a practical way Mr. Austin was in reality the discoverer of the septic tank. Nevertheless, the real significance of the septic tank —the fact that the changes going on are biological—was not appreciated by him, as is shown by his calling it a "mechanical process for separating the solid matter of sewage." Nor, indeed, does anyone seem to have appreciated the significance of these tanks, although a number of them were built and operated in England, with such success as is possible for that kind of a tank, but the so-called chemical purification process forged rapidly to the front, and mechanical separation—which is now called septic action—was lost sight of for a number of years, and chemical purification became for a time the leading form in England.

In the meantime, land purification processes, where the proper conditions obtained, were slowly gaining ground. These processes have always labored under this disadvantage, that not being in any way subject to patent, they have never had the booming which chemical precipitation and purification by septic action have received, although whether this is so great an advantage may, perhaps, be an open question. At any rate, the progress which such processes have made, while slow, has nevertheless been sure, until we are justified in saying that where proper conditions obtain, broad irrigation and intermittent filtration are, all things considered, the most satisfactory systems yet worked out. As a broad proposition, in consideration of the value of the crops produced, broad irrigation is the cheapest system yet devised. Experiments at Berlin, Paris, Croyden, Doncaster, Birmingham and other places, show that large crops may be produced and eaten without prejudice to health.

Let us now consider the recent development of sewage purification by means of bacterial action. This has been a favorite subject for consideration by a number of biologists, scientific writers, etc., for a good many years. The history of the matter will not be gone into at length at this time, any further than to point out two or three significant guide posts along the line. Like all other discoveries, its development has been gradual, and is the work of many men instead of one.

As far as can be learned, Dr. Alexander Mueller was the first person to appreciate clearly that bacteria were the prime agents in sewage purification. About 1880, Dr. Mueller took out a patent, endeavoring to utilize the micro-organisms in sewage for purposes of purification. Works were built under this patent, and were in operation for some time, to purify the effluent of a manufacturing establishment for beet sugar. Dr. Mueller says:

"The contents of sewage are chiefly of organic origin, and in consequence of this, an active process of decomposition takes place in

sewage, through which the organic matters are gradually *dissolved* into mineral matters, or, in short, are mineralized, and thus become fit to serve as food for plants. To the superficial observer this process appears to be a chemical self-reduction; in reality, however, it is chiefly a process of digestion, in which the various, mostly microscopically small, animal and vegetable organisms utilize the organically fixed power for their life purposes. Mr. Rafter.

"The decomposition of sewage in its various stages is characterized by the appearance of enormous numbers of spirilla, then of vibrios (swarming spores), and, finally, of moulds. At this stage commences the reformation of organic substance, with the appearance of the chlorophyl-holding protococcus, etc."

In the meantime, in December, 1881, and January, 1882, an account of Mouras' automatic scavenger was published in France. This apparatus consists of a closed vault with a water-seal, which it is stated rapidly transformed excrementitious matters into a homogeneous fluid, only slightly turbid, and holding the solid matters in suspension in the form of scarcely visible filaments. The principle upon which the automatic scavenger acts is that animal dejecta contain within themselves all the principles of fermentation necessary to liquify them and to render them useful. Later observations show that Mouras' view, that animal dejecta contain within themselves the fermentative principle, is fundamentally true, and, in this particular, Mouras, with Dr. Mueller, was in advance of the scientific workers of that day.

A number of investigators were at work upon the general problem, and in May, 1886, Dr. Dupré, in discussing a paper of Dr. Tidy's, at the Society of Arts of England, proposed to cultivate bacteria on a large scale, discharging them with an effluent into a river where they might be expected to further purify sewage.

In January, 1887, Mr. Dibdin read a paper, before the Institution of Civil Engineers, in which he discussed the propriety of using large quantities of lime. At that time many chemists claimed that lime was especially valuable in sewage purification because it destroyed living organisms, such as bacteria, which give rise to putrefaction, the idea being that, if all the organisms could be destroyed, sewage would be rendered innocuous. Mr. Dibdin took the ground that the very essence of the sewage purification is not the destruction of bacterial life, but is the resolution of organic matter into other combinations. Hence, it follows that an antiseptic process is the very reverse of the object to be aimed at. That is to say, a septic process is required, and hence the name septic sewerage applied later on to designate this process.

In November, 1887, the Massachusetts State Board of Health commenced their classical experiments on the purification of water and sewage by filters. The first two volumes of the reports, published in 1890, laid the foundations of the modern development of bacterial

Mr. Rafter. sewage purification processes. The experiments were carried out with an unparalleled wealth of detail, and, taken all in all, they are still unapproached by work done anywhere. The reports have been continued from year to year down to the present time. As far as known to the writer, no criticism of the work of the Massachusetts State Board of Health has ever been made, except that their experiments were on somewhat too limited a scale to be entirely comparable with practice, nevertheless, the general deductions have been confirmed at a very large number of sewerage works, both in Europe and America.

An English engineer, W. D. Scott Moncrieff, constructed experimental works for the bacterial purification of sewage in 1891. He constructed a bacterial tank, in which the old principle of upward filtration was applied, the crude sewage being admitted from below and gradually flowing upward through a bed of stones. In this way he found that the liquefaction of solids was so effective that the sludge of ten persons was absorbed on 9 sq. yds. of land. The space beneath had a capacity of less than 5 cu. ft., and would obviously have filled up except for the liquefying action which had taken place.

In 1892, Mr. Dibdin began his experiments on filtration through coarse material, such as burnt ballast, coke breeze, gravel, etc., the object being to obtain a high degree of porosity, with power of reabsorbing atmospheric oxygen. In the first series of experiments made, wooden tanks, with an area of $\frac{1}{200}$ of an acre, were used.

In the second series, the filter covered an acre of land, the material consisting of 3 ft. of pan breeze, with 3 ins. of gravel. These experiments were continued from September, 1892, to November, 1896. Space will not be taken to indicate the results, any further than to say that, generally, the bacterial purification of sewage was advanced considerably thereby.

In the meantime, Mr. Dibdin had also conducted experiments for the Sutton Urban District Council, and, in 1896, constructed a bacteria tank for that authority. This tank was fairly satisfactory, and, in 1897, the District Council gave orders for a second tank to be turned into a similar bacteria bed for treating crude sewage. The first tank was filled with raw sewage entirely untreated except that it had been strained through a screen to intercept the grosser particles. During seventy-six days, sewage was treated at the rate of 773 000 galls. per acre per day, rest period included. In the London experiments, 1 000 000 galls. of the effluent from chemical precipitation were treated on the burnt ballast bed of one acre, as against about 60 000 galls. per acre per day treated through coarse sand, as per the system of the Massachusetts State Board of Health.

About 1897, Mr. Cameron designed and placed in operation at Exeter, England, a septic tank. This tank is the septic tank as we

now understand it. Its features are the reception of sewage, without any preliminary treatment, in a covered tank having a capacity equal to anywhere from 12 to 24 hours' flow of sewage. The cross-sectional area of this tank is large enough to permit the sewage passing very slowly through it, thereby depositing the heavy matters, leaving only the lighter ones to pass forward with the water to the coke breeze filter beds, constructed on the same plan as in the London experiments. A comparison of the plans of Mr. Cameron's tanks shows that in the essentials it is similar to the tank in use at Cheltenham, England, and also the experimental tank proposed by Mr. Austin in his report of 1857. To appreciate this fact, one needs to have Mr. Austin's report before him, together with plans of a Cameron tank. Mr. Rafter.

The septic tank has been experimented upon by the Massachusetts State Board of Health, and a large amount of valuable matter is given in the reports of 1898–1901, inclusive. These experiments, however, are on somewhat too small a scale to be decisive, although probably the main conclusions will be verified by more extended experiments. The most satisfactory experiments carried out in the United States have been made at Worcester, Mass.

As to the success attained in the purification of septic sewage, as a whole, the results are somewhat contradictory, although, under certain conditions, the process may be a material addition to a sewage purification plant, but success cannot be depended upon in every case. Apparently, a distinction must be made between fresh, stale and septic sewage, and sewage mixed with refuse manufacturing waste, such as refuse from tanneries, slaughter-houses, acid works, cheese factories, etc. All these different forms of pollution need to be experimented upon before a final general rule can be formulated.

As regards the treatment of fresh sewage, the results indicate that an accumulation of sludge within the septic tank must be expected, and amounts to a considerable percentage of that originally present in the sewage on entering the tank. Enthusiastic advocates of bacterial purification have affirmed an entire doing away with the sludge difficulty, but, thus far, this claim has not been verified. The sludge difficulty still remains, and when sewage works are operated on a large scale, will be the source of considerable trouble in the future, as it has been in the past.

With stale sewage, which has undergone mechanical, chemical and bacterial action while flowing through the sewers, it is possible that the action in the tank will be much more satisfactory than in the previous case. Experiments indicate that a considerable proportion of the organic matter in suspension will be removed either by liquefaction or by changing to a gaseous form, and that its effluent can easily be further purified by filtration.

In the case of septic sewage, which has already been subjected to

Mr. Rafter. bacterial action, further bacterial processes may not only be unnecessary, but even harmful, because they render sewage difficult to purify by subsequent oxidation.

As to the effect on sewage containing manufacturing wastes, the report of Messrs. Kinnicutt and Eddy, "The Action of the Septic Tank on Acid Iron Sewage," is perhaps the most authoritative of any experiments thus far instituted. These gentlemen state that from the slow passage of an acid iron sewage containing an amount of organic matter, represented by about one part of albuminoid ammonia in one hundred thousand parts, an amount of iron in solution from five to eight parts and the free acid in terms of sulphuric acid about ten parts in one hundred thousand parts, the following results may be expected:

"(1) That about one-fourth of the total solid matter contained in the sewage will be removed.

"(2) That the effluent from the tank will contain about 20% less soluble matter than the crude sewage, owing to the soluble matter in the sewage being decomposed or changed into insoluble substances.

"(3) That the amount of suspended matter removed from the sewage will not greatly exceed 30% unless special precautions are taken to retain in the tank the finely divided iron sulphide, formed by the reduction of the soluble iron sulphate in the sewage.

"(4) That the amount of organic matter removed from the sewage, as determined from the albuminoid ammonia, will average from 20 to 25 per cent.

"(5) That, of the suspended matter, the amount removed will average a little under 50%, and that the amount of soluble organic matter removed will not average much more than 10% of the soluble organic matter in the sewage."

It is also stated that while the sludge from such a tank will be proportionately from 60 to 70% of the original, nevertheless, not more than 50% will require to be removed, owing to the fact that the sludge in a septic tank contains less water than in a sedimentation tank.

The definite results gained by the Massachusetts State Board of Health and at Worcester show that the purification effected by a septic tank is so slight as to be of very little advantage, and the septic tank, alone, cannot be considered a means of sewage purification. It must be considered a method of transformation, merely.

In conclusion, the writer's view is that while the septic tank, and purification by bacteria generally, has considerably advanced our knowledge of sewage purification, nevertheless, as a method, it will, in the end, take its place with mechanical separation, chemical purification and many others, which have been temporary fads only, but that land purification processes, where there is suitable land available, have the advantage of not only effective purification, but, by reason of the value of the crops, make possible a partial or complete return on the outlay. Where suitable land is not available, less efficient processes are permissible.

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PAPERS AND DISCUSSIONS.

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THEORY OF CENTRIFUGAL PUMPS AND FANS: ANALYSIS OF THEIR ACTION, WITH SUGGESTIONS FOR DESIGNS.

Discussion.*

By Messrs. William Mayo Venable and E. T. Adams.

William Mayo Venable, Assoc. M. Am. Soc. C. E. (by letter).— Mr. Venable.
This paper is very interesting, as it points out some facts not generally understood; but the writer cannot agree with the theory advanced, which is based partially upon an erroneous assumption, and neglects the effect of the vanes acting in any direction other than that of rotation. The conclusion concerning the possible improvement of centrifugal pumps by adopting a type of pump with a nozzle, or contraction of the opening, at the tips of the blades, producing a high radial velocity of flow there, is entirely erroneous.

Apply the author's Equation I to the particular case used as an illustration on page 495,† as follows:

$$V^2 - V^2_1 = u^2 - u^2_1.$$
$$6.8^2 - 8.6^2 = 57^2 - u^2_1;$$

whence u_1 must be greater than u, which is mechanically impossible.

The paper makes

$$V^2 = V^2_1 + u^2 - u^2_1,$$

*This discussion (of the paper by Elmo G. Harris, M. Am. Soc. C. E., printed in *Proceedings* for May, 1903, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to October 23d, 1903, will be printed subsequently.

† *Proceedings*, Am. Soc. C. E., for May, 1903.

Mr. Venable. or V is the velocity produced by a pressure head of

$$\frac{V^2_1 + u^2 - u^2_1}{2g} = \frac{v^2_1 + u^2}{2g}$$

discharging water through an orifice against no external pressure.

In order that the author's formulas may hold, the first condition must be that there shall be no pressure head whatever at the orifice at the tips of the blades. But any pump that discharges water against a head must produce a head equal to the head worked against and also a head sufficient to give the water the necessary velocity, v_1, to enter at the intake; that is, a velocity necessary to pass the required quantity through the smallest section of the suction passage, assuming that from there on the pump has no losses.

But the velocity, V, reduced to zero by enlarging the discharge passages, would only create head worked against, if the pressure at the tips of the vanes is zero; and this would leave no source of head to produce the flow at the intake, v_1. V, therefore, can never be as great as the formula requires.

Consequently, the formula,

$$v^2 = V^2 + u^2 + 2\,u\,V \cos.\ \beta,$$

cannot apply, because V is not a real velocity, but a hypothetical velocity, which is in reality represented by a less velocity, and an actual pressure head.

A proper understanding of the relation between velocities and pressures in a pump must be based on first principles.

"Centrifugal pumps," "screw pumps," "turbine pumps," and all other kinds of pumps in which the flow of water is unidirectional and uniform; that is, all pumps not provided with reciprocating parts, depend upon increasing the velocity of the water by means of moving vanes or orifices and retarding that velocity by passing the water through a channel of enlarging section. Both the increase and the diminution of velocity are accompanied by the production of useful head. Water motors of the corresponding types only reverse the process, and develop mechanical motion.

If v is the velocity of motion of water past an orifice, normal to its opening, and if the pressure within is such that water does not enter, h is the head at the mouth of the orifice, and

$$v^2 = 2\,g\,h.$$

But, if h does not balance the tendency of the water to enter the orifice, and water flows in with a velocity, v_1, losing a velocity, v_2,

$$v = v_1 + v_2,$$

the velocity head remaining in the water is

$$h_1 = \frac{v^2_1}{2g},$$

and the pressure head at the orifice is

$$h_2 = \frac{v^2 - v^2_1}{2g} = \frac{v^2_2 + 2\,v_1\,v_2}{2g}.$$

Mr. Venable.

Therefore, if h_2 and v are known, v_1 can be found, for

$$v^2_1 = v^2 - 2\,g\,h_2 = 2\,g\,(h - h_2).$$

If Q is the quantity entering the orifice per second, and a is the area of the orifice,

$$Q = a\,v_1 = a\,\sqrt{v^2 - g\,h_2} = a\,\sqrt{2\,g\,(h - h_2)}.$$

If the pump consists of this simple orifice without other devices affecting the flow or pressure (a purely ideal condition, mechanically impossible), the work lost in making water flow through the orifice is proportional to $Q\,v^2_1$, and the useful work is proportional to $Q\,(v^2 - v^2_1)$. The efficiency, therefore, is $\frac{v^2 - v^2_1}{v^2} = \frac{h_2}{h}$, and the loss ratio is $\frac{h_1}{h}$.

These formulas hold good, not only for a simple orifice, but for any device in the form of a fixed passageway where the water changes its velocity from v to v_1 without friction or internal currents; for instance, it applies to a passage which has a smaller section where the water enters than where it emerges, and to the openings between blades on ordinary centrifugal pumps.

Besides the loss due to h_1 there are also friction losses. These may be divided into three classes:

1.—Friction of water on the surface of the pump parts;

2.—Friction of water on water, due to ordinary changes in velocities which cannot be avoided;

3.—Friction of water on water caused by abrupt changes in the direction of flow, so that the water is disturbed unnecessarily, owing to imperfection in design.

Necessarily, the process of taking water at an orifice, if the water be assumed as stationary and the orifice moving, must be accompanied by a counter process, that of discharging the water through another orifice, and reducing its velocity again to rest. This implies two sets of orifices or passages, one set moving and one set fixed. In a pump, the motion of the water, relative to the passage in which it is flowing, should be a continuous process of retardation. Its actual velocity undergoes, first, a process of acceleration, and, second, a process of retardation. In a motor, the motion of the water relative to the passage in which it is flowing is a continuous process of acceleration. Its actual velocity undergoes changes similar to those in a pump, but with velocities reversed in direction.

An impervious surface moving in a liquid, neglecting friction, can produce a velocity only normal to its face. It must produce a velocity equal to the component of its velocity normal to its face, as otherwise the liquid would pass through the surface. The actual velocity of the liquid must be the result of the velocity of the motion of the surface, normal to itself, and of some velocity, parallel to the surface, not affected by its motion.

If the surface of the plate is normal to the direction of its motion, it produces velocity only in the direction of its actual motion.

Mr. Venable. A series of such surfaces arranged radially around an axis may be called a simple centrifugal pump.

Let r = radius at any point on the surfaces;

ω = angular velocity, in revolutions per second;

v = actual velocity of the surface at any point;

$v = 2\,\pi\,r\,\omega$.

The centrifugal force is the result of restraining the velocities, v, into circular paths. If the water is at rest between r_1 and the axis of rotation, the centrifugal force due to rotation between r_1 and r_2 produces a head,

$$h = \frac{v^2_{r_2} - v^2_{r_1}}{2\,g}.$$

If there is no flow, the water will be set in motion from the axis out, and the head becomes

$$h = \frac{v^2_{r_2}}{2\,g},$$

which is the same as the $\frac{u^2}{2\,g}$ derived by Mr. Harris.

This head is the head produced by retarding the velocity, v_{r_2} to 0.

The head, $\frac{v^2_{r_2} - v^2_{r_1}}{2\,g}$, is the head produced by retarding the water from v_{r_2} to 0, less the head required to give it the velocity, v_{r_1}, necessary to enter between the plates.

Call the radial velocity through the pump w. The motion of rotation cannot affect this velocity, which is parallel to the blades. Therefore, w must be produced by the head, $\frac{v^2_{r_2} - v^2_{r_1}}{2\,g}$; leaving a head, $\frac{v^2_{r_2} - v^2_{r_1} - w^2}{2\,g}$, remaining. This is 0 when $v^2_{r_2} = v^2_{r_1} + w^2$.

It does not matter whether w has its maximum value at r_1, as is usual, or whether it has its maximum value at r_2, as Mr. Harris suggests, as far as the fact that it must be produced by the pump is concerned. The maximum value must be used in the equation given.

w should have its maximum value at r_1, because that is the natural place for the smallest section of the pump, and nothing is gained by shifting it outward. The actual size of the orifice at r_1, measured around the circumference of the circle and corrected for the angle at which the water enters is, in the case of radial vanes,

$$a = 2\,\pi\,r_1\,b_1\,\frac{w}{\sqrt{w^2 + v^2_{r_1}}} = 2\,\pi\,r_1\,b_1\,\sin.\,\theta,$$

where b_1 is the width of the vanes at r_1, and θ is the angle included

between the direction of the water and the direction of motion, just within the vanes at r. Mr. Venable.

Such a pump would have large friction losses at r_1 where the velocity, v_1, is suddenly produced. This can be avoided by inclining the vanes to admit the water gently; but this introduces other elements into the design.

The following equations are illustrated by reference to Fig. 36.

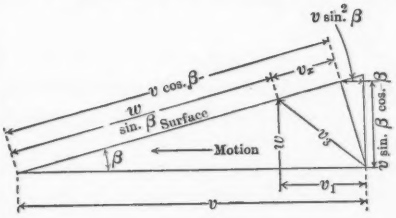


FIG. 36.

A surface is inclined at an angle, β, to the direction of its motion. Its velocity of motion is v. The component of this, normal to the surface, is $v \sin. \beta$. w is the velocity of flow normal to the direction of motion of the surface. v_1 is the velocity of motion of the water parallel with the motion of the surface, however produced. The actual flow of water is represented by v_3.

$$v^2_3 = v^2_1 + w^2 = v^2 \sin.^2 \beta + v^2_x.$$

v_x is the velocity of the water measured parallel with the surface.

$$w = (v - v_1) \tan. \beta,$$

$$v \sin. \beta = v_1 \sin. \beta + w \cos. \beta;$$

$$v_x = \frac{v_1 - v \sin.^2 \beta;}{\cos. \beta} = v \cos. \beta - \frac{w}{\sin. \beta};$$

or,
$$v \cos. \beta = v_x + \frac{w}{\sin. \beta}.$$

If we consider two such plates, parallel to one another, with an orifice between them, the identity of this expression,

$$v \cos. \beta = v_x + \frac{w}{\sin. \beta},$$

with the expression derived for a moving orifice, $v = v_1 + v_2$, will be easily seen. The other formulas for an orifice can be readily applied to this case.

The plate, however, does not move actually against water at rest. It produces a velocity, $v \sin.^2 \beta$, in the direction of its motion.

$$h_1 = \left(v^2 \cos.^2 \beta - \frac{w^2}{\sin.^2 \beta} \right) \div 2g$$

is the pressure head at the orifice.

$$h_2 = \frac{v^2_3}{2g} = \frac{v^2_1 + w^2}{2g}$$

is the velocity head actually present between the plates, which may be converted into head by proper retardation.

$$2g (h_1 + h_2) = v^2 \cos.^2 \beta - \frac{w^2}{\sin.^2 \beta} + v^2_1 + w^2.$$

But, since $v_1 = v - w \cot. \beta$,

$$2g (h_1 + h_2) = v^2 (\cos.^2 \beta + 1) - 2 v w \cot. \beta.$$

Mr. Venable. If we make $\beta = 90°$, we have again the case with radial vanes Then :

$$\sin.^2 \beta = 1\,;\ \cos.\ \beta = \cot.\ \beta = 0;\ v_1 = v;$$

$$h_1 = -\frac{w^2}{2g};\ h_2 = \frac{v^2 + w^2}{2\,g},\ \text{and}$$

$$h_1 + h_2 = \frac{v^2}{2\,g},$$

all of which correspond with previous results.

If, instead of plates, such as shown in Fig. 36, there are curved plates, as shown in Fig. 37, the same velocity, v_3, may be produced gently, instead of suddenly, with the same production of useful head. The actual cross-section of the stream of water increases as the velocity parallel to the blades diminishes. The velocity of flow along the plate is $\frac{w}{\sin.\ \beta}$. At the entrance, this is $\frac{w_1}{\sin.\ \beta_1}$, and at the discharge from the blades it is $\frac{w_2}{\sin.\ \beta_2}$. The head developed is

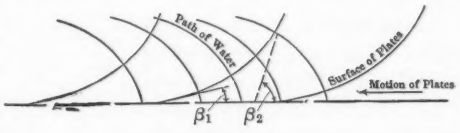


FIG. 37.

$$\left[\frac{w^2_1}{\sin.^2 \beta_1} - \frac{w^2_2}{\sin.^2 \beta_2}\right] \div 2\,g.$$

The total head produced by the moving orifice plus the curvature of the blades is

$$h_1 = \left[v^2 \cos.^2 \beta_1 - \frac{w^2_2}{\sin.^2 \beta_2}\right] \div 2\,g,$$

and the final velocity produced is

$$v^2_3 = (v - w_2 \cot.\ \beta_2)^2 + w^2_2.$$

If $w_1 = v \cos.\ \beta_1 \sin.\ \beta_1$, the water enters between the blades without producing any head at the orifice, but there is still there a velocity, $v \sin.^2 \beta_1$, causing friction with the water beneath. If $w_1 = v \tan.\ \beta_1$, there is no sudden change in the velocity at the entrance, but a slight head is required to make the water enter, on account of the component of the velocity of the plate, $v \sin.^2 \beta$, which must be overcome.

There may be a series of inclined blades arranged around an axis of rotation in one of two ways. These two arrangements are illustrated in Figs. 5 and 16.* In Fig. 5 the blades are arranged so that the water is intended to flow from the axis of rotation outward. In Fig. 16 the water flows in the same direction as the axis of rotation. Pumps with a radial direction for v are usually called "centrifugal"; the others are "screw" or "turbine" pumps. The same fundamental formulas apply, but they must be adapted to take into account the different values of v at various points on the blade, owing to variation in r. This variation affects the two classes differently.

* *Proceedings*, Am. Soc. C. E., for May, 1903.

Mr. Venable.

The manner of converting the velocity of water after it leaves the blades is also different in the two kinds of pumps. In the "centrifugal" type, one chamber which encloses the pump collects all the discharges between the vanes and retards their velocity. In the other case, deflector plates must be used to reduce all the velocities to one direction and intensity.

In the case of the centrifugal type, the formula becomes

$$2\,g\,(h_1 + h_2) = (2\,\pi\,w)^2\,(r^2_2 + r^2_1 \cos.^2\,\beta_1) - 4\,\pi\,w\,r_2\,w_2 \cot.\,\beta_2.$$

If the width of the vanes is uniform $w_2 = \frac{r_1}{r_2}\,w_1$, and

$$2\,g\,(h_1 + h_2) = (2\,\pi\,w)^2\,(r^2_2 + r^2_1 \cos.^2\,\beta_1) - 4\,\pi\,w\,r_1\,w_1 \cot.\,\beta_2.$$

It will be seen that when r_2 is very large compared with r_1, the angle, β_2, is not very important; but that when r_2 and r_1 are not widely different, both β_1 and β_2 are of very great importance in producing head.

The following considerations should fix the curvature of the blades.

1.—β_1 must be such as to allow the water free entrance with w normal to the direction of rotation, when the pump is operating at the conditions for which it is especially designed.

2.—β_2 must be such as to produce the required head, in connection with the other dimensions of the pump, namely, r_1, r_2, and the width of the vanes as the water passes out.

3.—The curvature from β_1 to β_2 must be such as to give the water a continuous change in velocity as it passes through, and as nearly a uniform change from w to v_3 as possible.

The pump casing should also be formed so that the velocity, v_3, will be reduced gently and uniformly to the velocity in the discharge pipe. This implies a steady enlargement of the section of the passage, measured normal to the direction of flow.

Centrifugal force is incidental to changes in velocity, and its effect is included in a consideration of the specific effect of all velocity changes.

A pump, to attain the highest efficiency consistent with economical construction, must be designed for a particular speed, head and discharge. Change in any of these elements will affect the efficiency injuriously, or will not result in as good efficiency as can be secured at the same cost with a modified design. If a pump is to operate at various heads, its design should be adapted to secure the best results at some intermediate head, so that the average efficiency will be as high as possible.

The problem of designing a pump in which w is parallel with the axis of rotation is one of shaping properly the vanes and deflector plates at various radii so as to secure a uniform value of $h_1 + h_2$ at all radii. The formulas given herein are applicable for each particular

Mr. Venable. radius. It will readily be seen that sin. β_2 cannot advantageously exceed 90° in such a pump.

In a centrifugal pump it will be noticed that h_1 is positive only when

$$v \text{ cos. } \beta_1 \text{ exceeds } \frac{w_2}{\text{sin. } \beta_2}.$$

Therefore h_1 is larger the smaller $\frac{w_2}{\text{sin. } \beta_2}$.

Now, $w_2 \text{ cot. } \beta_2 = v - v_1$,

or, $\frac{w_2}{\text{sin. } \beta_2} = (v - v_1) \text{ cos. } \beta_2$.

The motion of the blade cannot possibly produce a motion of the water in contact with it greater than v in the direction of v, or v_1 is always less than v. Therefore, if cos. β_2 is negative, either w_2 is negative, or a negative head is being created by the curvature at β_2, owing to pressure developed at other points being consumed there in producing the velocity, v_1, greater than v. That part of the blade with cos. β negative must act as a motor opposing the pump. In fact, if cos. β_2 is made sufficiently great, w will become negative, and the pump discharge water in a reverse direction from the ordinary one.

To recapitulate: All pumps of the general class under discussion rely for their production of head upon the retardation of velocity of the water relative to the walls of the passages in which it is flowing. This retardation is in two sets of passages, one of which is moving, in which the water acquires a velocity which should not exceed the velocity of the moving walls, measured in the direction of that motion, and the other set of which is fixed, and enlarges in section in order to secure head from the actual velocity of the water as it enters the fixed passages.

The sum of the head produced in these two sets of passages is the total head of the pump, which must counterbalance opposing head, overcome friction, and create the velocity necessary to cause the water to enter between the blades at the intake.

Mr. Adams. E. T. Adams, Esq. (by letter).—Mr. Harris presents an exceedingly simple and sensible treatment of the theory of centrifugal pumps and fans. It is a subject regarding which, as Mr. Harris points out, very little valuable or accurate information has been published. It does not follow from this, however, as the paper leads one to infer, that nothing valuable or accurate is known regarding centrifugal pumps. It is probable that each of the principal builders of pumps of this class have in their practice anticipated many of the discoveries that Mr. Harris has made and set forth in this paper. It is certainly true that practically all the more important points presented by Mr. Harris were discovered independently in the practice of the Allis-Chalmers Company, and the writer feels the better able to express his appreciа-

tion of the merit of the discussion by Mr. Harris, because from the practice of that company he is able to give numerical results as a measure of the value of theories which Mr. Harris has approached entirely from a theoretical and mathematical standpoint. Mr. Adams.

The paper is an able and valuable contribution to a subject which, in the past, has not received, from our universities and their professors, the attention which its magnitude and theoretical interest justified.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM SHATTUCK LINCOLN, M. Am. Soc. C. E.*

DIED MAY 16TH, 1902.

William Shattuck Lincoln was born on May 19th, 1837, at Dennysville, near Eastport, Maine. He was the son of Theodore and Elizabeth (Lincoln) Lincoln. One of his great-grandfathers was Major-General Benjamin Lincoln, a distinguished soldier of the Revolution. Of his early life and schooling we have very scanty information. There is, however, evidence pointing to a residence for a time in Boston or, possibly, in Cambridge, though his name is not found on the Harvard rolls. But, however this may be, in his active and well-trained mind he had the best results that any school can give.

At the age of nineteen, following an older brother, he went West, and in October, 1856, we find him a Division Engineer, in charge of construction of the Cincinnati and Chicago Railroad, from Richmond to Logansport, Indiana. Here he remained until January, 1861, when he was appointed Principal Assistant Engineer in charge of construction of the Chicago and Cincinnati Railroad, between Logansport and Valparaiso, Indiana. Both these lines now form parts of the Pennsylvania Railroad line between Richmond and Chicago.

In July, 1865, he entered the service of what is now the Wabash Railroad Company, in which service he remained until his death—a period of nearly thirty-seven years. His first position in this service was that of Resident Engineer of the Western or Illinois Division of the Toledo, Wabash and Western Railway, with headquarters at Springfield, Illinois.

In June, 1868, he was appointed Chief Engineer of the Decatur and East St. Louis Railroad, built between these points as part of the Wabash System. Upon the completion of this line, in January, 1871, he resumed his position as Resident Engineer of the Western Division, a position which he retained for nine years. During this time he also acted as Consulting Engineer of the Lafayette, Bloomington and Mississippi, and of the Lafayette, Muncie and Bloomington, Railroads.

In January, 1880, after the Toledo, Wabash and Western Railway and the St. Louis, Kansas City and Northern Railway had been consolidated as the Wabash, St. Louis and Pacific Railway, Mr. Lincoln was appointed Engineer for the lines west of the Mississippi River.

* Memoir prepared by Robert Moore, Past-President, Am. Soc. C. E.

In September, 1881, he was appointed Chief Engineer of the whole system, with headquarters at St. Louis—a position which he held until his death.

In 1872 Mr. Lincoln married Lula, daughter of Captain Alvin M. Higgins, of Logansport, Indiana. This congenial and happy marriage was ended on May 4th, 1894, by the death of Mrs. Lincoln at their home in Logansport.

His own death occurred at St. Louis, on May 16th, 1902, at the Mullanphy Hospital, where, a few days before, he had undergone a serious surgical operation in the hope of obtaining relief from a severe neuralgic affection from which for years he had been an almost constant sufferer. He was buried by the side of his wife at Logansport, Indiana, leaving no children to survive him.

Mr. Lincoln was elected a Member of the American Society of Civil Engineers on December 5th, 1883. As an engineer, he was careful, thorough, conscientious and sound. The entire confidence reposed in him as an engineer and as a man, by those having the best possible means of judging him correctly, is shown abundantly by his long-continued service with one railroad system, through many vicissitudes of management, reorganization and control. But, complimentary as was this long service with one corporation, it had the effect, when coupled with his retiring and home-loving disposition, of limiting the range of his acquaintance as well as the scope of his professional work; so that he was not as widely known as his great merits would otherwise have made him. By those, however, who had the opportunity of knowing him he was held in the highest esteem. Unassuming and unselfish, clear-headed and strong, with a cheerful fortitude which years of suffering could not shake, he was a man of noble type whom it was a privilege to count as a friend, and whose memory is a lasting possession to all who knew him.

GEORGE HENRY MENDELL, M. Am. Soc. C. E.*

DIED OCTOBER 19TH, 1902.

George Henry Mendell was the eldest of four children—a girl and three boys—all of whom he outlived.

He was born on October 12th, 1831, in the Village of Youngstown, Westmoreland County, Pennsylvania, from which place his parents moved to Blairsville in the adjoining County of Indiana in 1837.

* Memoir prepared by Messrs. C. E. Grunsky, L. J. Le Conte and Marsden Manson, Members, Am. Soc. C. E.

His father, George S. Mendell, was a teacher, and evidently gave his son a very thorough grounding in English, Latin, Greek, and the rudiments of mathematics, which was followed by the instruction given in the Blairsville Academy, by R. McCall, a graduate of Jefferson College. The course in the Academy embraced Historia Sacra, Cæsar's Commentaries, Virgil's Bucolics, Georgics and Æneid, Horace, Cicero's de Officiis, de Senectute and Amicitia, etc., in Latin, and the Anabasis and the Iliad, in Greek, with some mathematics. This course was completed in the years 1843–47 in very creditable style.

During two years of this time he was also an instructor, and received his own instruction free.

In the autumn of 1847, at the age of 16, young Mendell undertook to teach school for four months, which duty he performed very creditably for the modest pay of $20 per month.

In 1847–48, during a visit to relatives in Massachusetts (the native State of his parents), he heard of West Point Military Academy, and, through his own exertions, obtained the appointment from Congressman Buffington, entered on July 1st, 1848, and was graduated third in his class in 1852. He selected the Topographical Engineer Corps as his line of service, which corps, during the war, was consolidated with the Engineer Corps, in which he remained until he was retired at the age of 64 in 1895.

He was Assistant Topographical Engineer on the survey of the Northwestern Lakes, in 1852–54, then on the staff of Major-General Wool, commanding the Department of the Pacific in 1854, at which time the advantages of the Pacific Slope made a lasting impression on his mind.

He was thereafter assistant on a railway exploration survey from San Francisco to Fort Yuma, and later, in 1855 and 1856, on an expedition against hostile tribes in Oregon and Washington Territories. From 1856 to 1858, he was in charge of the construction of military roads in Oregon and Washington Territories. He was then called to the Military Academy at West Point, and served there as Assistant and Principal Assistant Professor of Natural and Experimental Philosophy.

At the outbreak of the War of the Rebellion he was assigned to Colonel Miles' Division in the Manassas Campaign, and thereafter rendered valuable service on special duty and in command of the United States Engineers' Battalion in reconnoissance work, building, guarding and destroying bridges, constructing batteries, blockhouses, rifle-trenches, making and repairing roads, and in carrying on siege operations at Petersburg, Va. He was Assistant Engineer on the defenses of Baltimore, Maryland, in 1864. After again serving as instructor in the Military Academy for a year, to which duty he had been assigned to recover from disabilities incurred in the field, he was

for a brief period Superintending Engineer of harbor defense works at New Bedford, Massachusetts, and of the work for the preservation of Plymouth Beach.

In 1867 he was transferred to California, and took charge of the fortification work of Alcatraz Island and Lime Point, in San Francisco Harbor, and, soon after, the defenses at the mouth of Columbia River and of Fort Point, San Francisco.

His activity was not confined to his Government work, which included the Wilmington Harbor breakwater, examination and survey of Estero Bay and San Diego Harbor, the removal of Rincon Rock in San Francisco Bay, the improvement of Oakland Harbor and of the Sacramento and Feather Rivers and of the construction of San Francisco Harbor defenses, for he was a member of the Commission appointed in 1874 to examine the irrigation possibilities in California. He was a member and President of the first California Débris Commission to regulate hydraulic mining. He was on the Commission to select a site for a naval dry dock on the Pacific Coast north of Latitude 42°, and on the Commission to select a site for a military post in San Diego, California, and of the Board of Engineers for the planning of Pacific Coast defenses.

Colonel Mendell was consulted by the City and County of San Francisco in reference to the sufficiency of the City Hall concrete foundation. In 1876-77 he was entrusted by this city with the examination of possible sources of water supply, and made an exhaustive report, which has proved of great value to the city. From 1878 to 1880 he was Consulting Engineer to the State of California, acting as an adviser to the State Engineer, who was charged with the investigation of irrigation, drainage and mining débris problems. He was also a member of the Sewerage Commission for the City and County of San Francisco, appointed in 1892 by the Board of Supervisors.

At the time of his retirement he was the Senior Colonel in the Engineer Corps of the United States Army.

Among the works with which he was more or less prominently connected as Consulting Engineer subsequent to his retirement may be mentioned the Portland Water-Works, the appraisement of the Los Angeles Water-Works, the examination of the water supply possibilities for Berkeley, the drainage project for Reclamation District, No. 108, in the Sacramento Valley, and the Red Bluff Water-Works.

He was selected by Mayor James D. Phelan to serve under a new city charter as President of the first Board of Public Works for the City and County of San Francisco, from January 8th, 1900, for three years. His efficient service in organizing this new department, which benefited by his long experience, his thoroughness as an engineer, and his ripe judgment, are thoroughly appreciated by those who have been in a position to judge of the results. His term of office was drawing to a close at the time of his death.

Colonel Mendell was one of the founders of The Technical Society of the Pacific Coast, and was made its first President in 1884, serving in this capacity for two terms.

General William P. Craighill, Past-President, Am. Soc. C. E., a life-long friend and fellow officer of the Corps of Engineers, writing of Colonel Mendell, says:

"I have known him since 1849, when I went to West Point, and our acquaintance began with my first appearance as a 'plebe' in the squad he supervised as drill-master. He was then, as he always was, a man who did his duty well and thoroughly; but there was a gentle way in his manner, tone and expression, which proclaimed him, as he always was in every relation of life, a gentleman, the highest type of man.

"I do not know that I can say more in praise of my dear friend than that, after an intimate acquaintance of more than fifty-three years I have always found him to be a real Christian gentleman, and I believe this will be the verdict of everyone who knew him. His mental ability none can deny. It was great; far beyond the average."

L. J. Le Conte, M. Am. Soc. C. E., who was his chief assistant for twenty-one years, has this to say:

"I have served under Col. Mendell, both on public as well as on private works and have uniformly felt the genial warmth of his friendship and the sound wisdom of his counsels. He was eminently fitted to supervise, and did so with the fullest regard to the preconceived opinions of those beneath him, and yet withal used such consummate tact as to make everyone feel an everlasting regard for him and his conclusions. Few men were gifted in this regard as he, and still fewer could smooth over seemingly insurmountable differences, and bring everything down to one harmonious conclusion. His loss will be greatly felt by the entire community, which he so faithfully represented. Peace to his ashes."

In 1858 he was married to Ellen Adair, daughter of the late John Adair, Esq., Collector of Customs at Astoria, Oregon, and grand-daughter of General John Adair, Governor of Kentucky, Senator and Representative in Congress, a revolutionary soldier who re-entered the service of his country in the war with England in 1812, and commanded the Kentucky troops at the battle of New Orleans. This union of two congenial spirits proved a happy one. Through forty-four years they lived in affection and love, devoted to each other and to their children. At the end of that time, while resting on her arm and being administered to by her loving hand, Colonel Mendell, with his mind clear and his eyes looking in her anxious face, closed them to all earthly things, while his pure spirit took its flight to the better realms, there to await the coming of hers.

A just estimate of Colonel Mendell's worth and appreciation of his professional work is fittingly expressed in the words of the Chief of the Engineer Corps of the United States Army, who, in sending out notice of his death, says:

"Colonel Mendell's record for distinguished service, his high attainments, his purity of life, and his sincerity of purpose, in all matters

relating to either private or public official work, have never been excelled by any officer whose record has appeared upon the rolls of the Army."

His entire life, from boyhood to the ripe age of seventy-one years, was crowded with active responsibilities far beyond those which fall to the average man. All these he met and discharged with the highest ability and integrity. In these crowded duties, he still found room for the exercise of a benevolence rarely equalled in its usefulness. He was one of the founders of St. Luke's Hospital, in San Francisco, and for many years one of its Directors, and never ceased to take an interest in the welfare of that institution.

Gentle, noble, and great in the discharge of every duty, he left kind memories with all who knew him.

Col. Mendell was elected a Member of the American Society of Civil Engineers on September 6th, 1876, and served as its Vice-President from January 20th, 1897, to January 18th, 1899.

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GEORGE F. SWAIN,	JOSEPH O. OSGOOD,	EMIL KUICHLING,
RICHARD S. BUCK,	FRANK C. OSBORN,	WILLIAM JACKSON,
WILLIAM J. WILGUS.	GEORGE S. DAVISON.	CHARLES WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

ON RAIL SECTIONS:—G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 533 Columbus
CABLE ADDRESS, - - - - - "Ceas, New York."

Vol. XXIX. OCTOBER, 1903. No. 8.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

October 7th, 1903.—The meeting was called to order at 8.50 P.M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 90 members and 10 guests.

The minutes of the meetings of September 2d and 16th, 1903, were approved as printed in *Proceedings* for September, 1903.

Messrs. Alfred W. Trotter, F. F. Harrington and Arthur S. Tuttle were appointed tellers to canvass the ballot on the proposed amendment to the Constitution.

A paper entitled "South African Irrigation," by Francis Robert Johnson, M. Am. Soc. C. E., was presented by the Secretary.

The tellers appointed to canvass the ballot on the proposed amendment to the Constitution* reported as follows:

Total ballots received		616
Without signature	3	
Not entitled to vote	10	
Otherwise defective	17	
		30
Total votes counted		586
Voted "yes"	537	
Voted "no"	49	
		586

The President declared the amendment adopted.

E. L. Corthell, M. Am. Soc. C. E., addressed the meeting informally, and described certain commercial, agricultural and engineering features of the Argentine Republic.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Charles Albertson, Kobe, Japan.
Frederick Wagoner Bennett, Guayaquil, Ecuador.
William Lewis Breckinridge, Chicago, Ill.
Frederick Anderson Burdett, New York City.
Edward Pontany Butts, Holyoke, Mass.
Albert Carr, New York City.
Albert Ladd Colby, South Bethlehem, Pa.
William Weeden Cole, Elmira, N. Y.
Fred Steere Darling, Montreal, Que., Canada.
Samuel Brownlee Fisher, St. Louis, Mo.
William Johnson Harahan, Chicago, Ill.
Benjamin Hurt Hardaway, Columbus, Ga.
Chapman Love Johnson, Tomhannock, N. Y.
Anson Marston, Ames, Iowa
Donald Alexander Matheson, Glasgow, Scotland.
Frank Moberly, Victoria, B. C., Canada.
Mason Mathews Patrick, Washington, D. C.
Henry Willis Post, New York City.
Frederick Perry Shearwood, Montreal, Que., Canada.
Samuel Alfred Taylor, Pittsburg, Pa.
Selwyn Mellon Taylor, Pittsburg, Pa.
Edward Baylies Thornhill, London, England.
Ross Francis Tucker, New York City.
Carl Uhlig, San Francisco, Cal.

* See *Proceedings*, for August, 1903, p. 195.

Edwin Frederick Wendt, New Brighton, Pa.
John T. Whistler, Washington, D. C.
Frank Wilcox, Pittsburg, Pa.
Chauncey Grant Williams, Brooklyn, N. Y.

As Associate Members.

George Marshall Beerbower, New York City.
Herbert Augustine Cresswell, Perth, Western Australia.
John Miller Cunningham, Pittsburg, Pa.
Charles Davis Drew, Cambridge, Mass.
Frederick Elbert Field, Pittsburg, Pa.
William Leonard Glazier, Newport, Ky.
Albert Worthington Hankinson, New York City.
Robert Graham Hengst, Chicora, Pa.
Engbert A Lee, Denver, Colo.
Elmer Gove Manahan, Paterson, N. J.
Guy Robert Ramsey, Ensley, Ala.
Samuel Palmer Senior, Bridgeport, Conn.
Mackey James Thompson, La Crosse, Wis.
Seth Morton Van Loan, Philadelphia, Pa.
Charles Austin Wentworth, Brooklyn, N. Y.
William Pharo Wiltsee, Kenova, W. Va.

The Secretary announced the election of the following candidates by the Board of Direction, on October 6th, 1903:

As Associates.

Frederick Snare, New York City.
Frederick Wilcock, Brooklyn, N. Y.

As Juniors.

Kenneth Mackenzie Cameron, Montreal, Que., Canada.
César Castellanos, Comitán, Chiapas, Mexico.
Kenneth Farra Cooper, San José, Cal.
Miles Penner Cotton, Winnipeg, Man., Canada.
David Mark Duller, Lake Charles, La.
E. Albert Gast, Cincinnati, Ohio.
Robert Walter Gay, Bayonne, N. J.
Charles Edward Gilman, San Francisco, Cal.
Harry Todd Griswold, Roxbury, Mass.
Harry Lewis Haehl, Coyote, Cal.
Henry Sydney Hancock, Jr., Newkirk, Okla.
Walter Scott Hanna, Boston, Mass.

HENRY PEREZ HOYT, Millinocket, Maine.
MARK LORIN IRELAND, Washington, D. C.
WILLIS ROBERT JORDAN, Cleveland, Ohio.
CLAUDE EAGLESON KEENE, McComas, W. Va.
SOL MCCRORY, Charleston, Ill.
RAY MURRAY, Philadelphia, Pa.
GEORGE ISRAEL OAKLEY, East Williston, N. Y.
WALTER JOHN PLOGSTED, Buffalo, N. Y.
ARMOUR CANTRELL POLK, New York City.
WILLIAM STANTON ROOT, New York City.
VICENTE SAUCEDO, Saltillo, Coahuila, Mexico.
WILBUR CYRUS SAWYER, Essex Junction, Vt.
FRANCIS RAUCH SCHMID, Bethlehem, Pa.
FREDERICK AUGUSTUS SHERWOOD, Germantown, Pa.
CHARLES HEYWOOD STRATTON, Annapolis, Md.
JAMES WOLFE SUSSEX, Newark, N. J.
DAVID YOUNGS SWATY, Pittsburg, Pa.
NORMAN ALFRED TAYLOR, Troy, N. Y.
WHITMELL PUGH TUNSTALL, Cleveland, Ohio.
HENRY RADCLYFFE ST. ARVANS WALTERS, Bethlehem, Pa.
ROYAL SYLVESTER WEBSTER, Kansas City, Mo.
FREDERICK WHITEFIELD WITHERELL, Pittsburg, Pa.

Adjourned.

October 21st, 1903.—The meeting was called to order at 8.40 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 103 members and 14 guests.

A paper entitled "Some Railway Construction in Oklahoma," by A. G. Allan, Assoc. M. Am. Soc. C. E., was presented by the Secretary, who also read communications on the subject from Messrs. Samuel H. Lea and Emile Low.

A second paper, entitled "The Fatigue of Cement Products," by J. L. Van Ornum, M. Am. Soc. C. E., was presented by the Secretary, who also read communications on this subject from Messrs. L. F. Bellinger, E. R. Buckley and A. L. Johnson.

The Secretary announced the death of CHARLES EZRA GREENE, elected Member January 4th, 1882; died October 17th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

October 6th, 1903.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Craven, Croes, Knap, Osgood, Pegram and Schneider.

William Jackson, Joseph P. Davis and Charles S. Gowen were appointed a Committee to prepare a memoir of the late Alphonse Fteley, Past-President, Am. Soc. C. E.

E. Gerber, H. G. Prout and C. C. Schneider were appointed a Committee to prepare a memoir of the late George S. Morison, Past-President, Am. Soc. C. E.

Charles Macdonald, William Metcalf and J. A. Ockerson, were appointed as Honorary Members (representing this Society) of the American Reception Committee of the Iron and Steel Institute in 1904.

Applications were considered and other routine business transacted.

Two candidates for admission as Associate and thirty-four as Junior were elected.*

Adjourned.

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*See page 375.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, November 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by Eugene Goetze, Esq., entitled "Filtration for Public Water Supplies, with Especial Reference to the Double Filtration Plant at Bremen, Germany," will be presented for discussion.

This paper was printed in *Proceedings* for September, 1903.

Wednesday, November 18th, 1903.—8.30 P. M.—At this meeting a paper by George Cecil Kenyon, Assoc. M. Am. Soc. C. E., entitled "Dock Improvements at Liverpool," will be presented for discussion.

This paper was printed in *Proceedings* for September, 1903.

Wednesday, December 2d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "A Desirable Method of Dredging Channels through River Bars," by S. Maximoff, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

This week has also been fixed for an International Engineering Congress, to be held under the auspices of a Committee appointed by the Exposition authorities, upon the recommendation of this Society.

It is also expected that the visit of members of the Institution of Civil Engineers to this country, by invitation of this Society, will be so timed that their participation in the International Engineering Congress will be assured.

As the details of the above matters are developed, they will be announced in *Proceedings*.

INTERNATIONAL ENGINEERING CONGRESS.

The following Committee, recommended by the Board of Direction of this Society, has been appointed by the President of the Universal Exposition, St. Louis, 1904, to take charge of an International Engineering Congress to be held at St. Louis during the week beginning October 3d, 1904:

Henry S. Haines,	M. Am. Soc. C. E.,	New York, N. Y.,	*Chairman.*
L. F. G. Bouscaren,	" "	Cincinnati, O.,	*Vice-Chairman.*
William Metcalf,	" "	Pittsburg, Pa.	
Benjamin M. Harrod,	" "	New Orleans, La.	
William P. Craighill,	" "	Charlestown, W. Va.	
M. T. Endicott,	" "	Washington, D. C.	
E. L. Corthell,	" "	New York, N. Y.	
Joseph Ramsey, Jr.,	" "	St. Louis, Mo.	
Robert W. Hunt,	" "	Chicago, Ill.	
L. B. Stillwell,	" "	New York, N. Y.	
A. A. Robinson,	" "	St, Louis, Mo.	
George B. Post,	" "	New York, N. Y.	
M. L. Holman,	" "	St. Louis, Mo.	
Palmer C. Ricketts,	" "	Troy, N. Y.	
Joseph M. Knap,	" "	New York, N. Y.,	*Treasurer.*
Chas. Warren Hunt,	" "	New York, N. Y.,	*Secretary.*

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an Engineering Exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

Robert Moore,	M. Am. Soc. C. E.,	St. Louis, Mo.,	*Chairman.*
Edward C. Carter,	M. Am. Soc. C. E.,	Chicago, Ill.	
Mordecai T. Endicott,	M. Am. Soc. C. E.,	Washington, D. C.	
James L. Frazier,	" "	Frankfort, Ind.	
William Jackson,	" "	Boston, Mass.	
Emil Kuichling,	" "	New York, N. Y.	
John F. Wallace,	" "	Chicago, Ill.	
H. J. Pfeifer,	Assoc. M. Soc. Am. C. E.,	St. Louis, Mo.,	*Secretary.*

LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 20, 1904.

The following list of nominees for the offices to be filled at the Annual Meeting, January 20th, 1904, received from the Nominating Committee, was presented to the Board of Direction at its meeting on September 1st, 1903. The list has already been mailed to all Corporate Members.

For President, to serve one year:

CHARLES HERMANY, Louisville, Ky.

For Vice-Presidents, to serve two years.

F. S. CURTIS, Boston, Mass.

S. L. F. DEYO, New York City.

For Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

For Directors, to serve three years:

N. P. LEWIS, New York City, representing District No. 1.

CHARLES S. GOWEN, Ossining, N. Y., representing District No. 1.

JOHN W. ELLIS, Woonsocket, R. I., representing District No. 2.

GEORGE S. WEBSTER, Philadelphia, Pa., representing District No. 4.

RALPH MODJESKI, Chicago, Ill., representing District No. 5.

CHARLES D. MARX, Santa Clara, Cal., representing District No. 7.

ACCESSIONS TO THE LIBRARY.

From September 9th to October 13th, 1903.

DONATIONS.*

THE ALTERNATING CURRENT TRANSFORMER.

By F. G. Baum. Cloth, 8 x 6 ins., 95 pp., illus. New York, McGraw Publishing Company, 1903. $1.50.

This book, as is stated in the preface, originated in a course of university lectures. It is intended for the general reader as well as the engineer. Some knowledge of elementary alternating currents is presupposed. Chapters I and II are introductory. Chapters III to V are intended to impart a knowledge of the transformer. The tests in Chapter VI are to be carried out by the student on a few commercial types. The chapter headings are: Elementary Principles; Simple Transformer Diagram; Graphical Representation of Pressure Relations; Regulation; Efficiency; Testing; Systematic Design; Circuit Regulators, Constant Current Transformers, Series Transformers, Compensating Voltmeter; Connections of Transformers for Single-phase and Polyphase Circuits; Commercial Types of Transformers; Extracts from Rules and Requirements of the National Board of Fire Underwriters. There is an index of seven pages.

COMPOUND CORLISS ENGINES.

By James Tribe, M. Am. Soc. M. E. Leather, 7½ x 5 ins., 177 pp., illus. Published by the Author, Milwaukee, Wis. $2.50.

The author states in the preface that this volume was intended as the second edition of his former work "Compound Engines," but so much new material has been added and so thorough has been the revision of the old, that it has become a new book. In its present form it is an elementary text-book on the generation and utilization of heat and the transformation of heat energy into mechanical energy by means of the multi-cylinder Corliss steam engine. The work aims to be practical in purpose, all the examples being based upon actual practice, and the data taken from engines which are built and running. It is intended to meet the needs of the steam engine designer whose knowledge of higher mathematics may be limited, and who finds himself handicapped by the usual complex formulas. The Contents are: Preliminary Investigation; Steam; Water for Steam; Heat-Energy; Economy of Expansion; Theoretical Diagrams; Horse-Power as a Standard Measurement for Work; Multiple Expansion; Steam Jackets; Single-Cylinder Engines; Double-Expansion Non-Condensing Engines; Double-Expansion Condensing Engines; Double-Expansion Pumping Engines; Triple-Expansion Engines; Quadruple-Expansion Engines; Receivers; Condensing Apparatus; Injection Water. There is an index of two pages.

ENGINEERING PRELIMINARIES FOR AN INTERURBAN ELECTRIC RAILWAY.

By Ernest Gonzenbach. Cloth, 9 x 6 ins., 71 pp., illus. New York, McGraw Publishing Company, 1903. $1.00.

In view of the present interest in interurban railway development and engineering the author submits, as the result of an invitation from the *Street Railway Journal*, the plans and recommendations embodied in a report on a proposed railway in the Middle West which serves as an example of the many roads now on paper, and which may soon assume tangible form. The book is not intended by the author as an attempt to generalize and instruct others in the art of railway construction, but is to show the way in which certain conditions were to be met in a certain case, together with the reasons which led to the recommendations and plans therein submitted. The Contents are: Introductory; Estimated Income; General Requirements; Third Rail *vs.* Trolley; Location; Roadbed and Track; Rolling Stock; Electric Car Equipment; Car Shops; Power Stations; Transmission Line; Distributing System; Third Rail; Accessories; Estimate; Operation; General Conclusions.

PRACTICAL HYDROSTATICS AND HYDROSTATIC FORMULAS.

By E. Sherman Gould, M. Am. Soc. C. E. Cloth, 6 x 4 ins., 114 pp., illus. New York, D. Van Nostrand Company, 1903. 50 cents.

The preface states that the object of this little treatise is to set forth clearly the fundamental laws of hydrostatics by which all practical problems may be readily solved, and to supplement them by a large number of deduced formulas embracing a wide

* Unless otherwise specified, books in this list have been donated to the Library by the Publishers.

range of application, the whole being made plain by an abundance of illustrative figures and numerical examples. The treatment of the subject includes the calculation of the buoyant effect of water upon immersed bodies. The Contents are: General Principles; Physical Properties of Water: Transmission of Water Pressure; General Law of Hydrostatic Pressure; Inclined Surfaces; Horizontal Thrust and Vertical Downward Pressure; Hydrostatic Paradox; Hydraulic Press; Special Cases of Hydrostatic Pressure; Examples for Practice; The Centre of Pressure; General Law for the Centre of Pressure; Centre of Pressure on Inclined Surfaces; General Formula; Practical Importance of the Position of the Centre of Pressure; Special Problems; General Principles; Law of Archimedes; Practical Application of the Law of Archimedes; General Law of Buoyancy.

MECHANICAL REFRIGERATION.

Being a Practical Introduction to the Study of Cold Storage, Ice-Making, and other Purposes to which Refrigeration is Being Applied. By Hal Williams, A. M. I. Mech. E., A. M. I. E. E. Cloth. 8 x 5 ins., 13 + 406 pp., illus. Whittaker & Co., London and New York, 1903 $2.25. (Donated by The Macmillan Company.)

In writing this book, the author has endeavored to confine himself to the practical issues rather than the purely technical. and thus to deal comprehensively with the questions of insulation, ice-making and cold storage from the standpoint of the owner and user. The Introduction explains the general principles of mechanical refrigeration, and is followed by two chapters on The Laws of Heat, Fluids, Liquids, Gases and Vapors and Thermo-Dynamics and Entropy. The next three chapters explain and describe Refrigerating Machines and are followed by chapters on the Refrigerating Plant; Auxiliary Plant; Insulation; Brine; Distilled Water; Ice-Making; Cold Storage; Articles in Cold Storage: Other Applications. This last chapter describes the application of refrigeration to the Brewery, the Dairy, etc. There is an index of seven pages.

IRON, STEEL, AND OTHER ALLOYS.

By Henry Marion Howe. Cloth, 9 x 6 ins., 18 + 457 pp., illus. Sauveur & Whiting, Boston, 1903. $5.00.

The preface states that this work was undertaken originally for the use of the author's students, to supplement the instruction given by lectures and other books. This it aimed to do by elaborating certain matters which are not treated at length, if at all, in other text books. The fact of writing a book fitted for students was an opportunity to go a little farther and try to meet the needs of practitioners, by giving them an account of the condition of the metallography of iron to-day, and more particularly to expose to them the present or solution theory of that metallography. The chapter headings are: Introductory; Cooling Curves; Freezing-Point Curves: Constitution of Binary Alloys which Form no Definite Chemical Compound; Other Series Curves of Binary Alloys Forming no Chemical Compound; Cooling Curves and Freezing-Point Curves of Series Containing Definite Chemical Compounds; Variations in Electric Conductivity and other Properties of Series of Alloys; The Metallography of Iron and Steel; The Heat-Treatment of Steel and Cast Iron; The Phase Rule; Progress in the Manufacture of Iron and Steel between 1880 and 1900; The Blast-Furnace; Metallurgical Gas Furnaces; Appendix. There is an index of seventeen pages.

THE MECHANICAL ENGINEER'S POCKET-BOOK OF TABLES, FORMULÆ RULES AND DATA.

A Handy Book of Reference for Daily Use in Engineering Practice. By the late D. Kinnear Clark, M. Inst. C. E. Fifth Edition, Revised throughout and Enlarged by H. H. P. Powles, M. I. M. E., A. M. Inst. C. E. Leather, 6 x 4 ins., 32 + 692 pp., illus. New York, D. Van Nostrand Company, 1903. $3.00.

This pocket-book has been prepared for the purpose of shortening the calculations and other intricate mental operations which are among the daily reourring needs of mechanical men. To meet such needs, there will be found about 350 tables of results of calculations relating to the principal branches of mechanical practice, which have either been compiled anew. or drawn from various sources. There are, in addition, about 500 formulas and rules, with data of general utility, classed for ready reference. For the fifth edition, the section dealing with electrical engineering has been largely rewritten, with additions, so as to adapt it to recent developments. In other sections, also, new matter has been added as required, thus bringing the work up to date. There is an index of eighteen pages.

THE PRACTICAL TESTING OF DYNAMOS AND MOTORS.

By Charles F. Smith, Assoc. M. Inst. C. E., A. M. I. E. E. Cloth, 9 x 6 ins., 8 + 231 + 3 pp., illus. Manchester, The Scientific Publishing Company. 5 shillings, net.

This little book is intended to serve as an elementary introduction to the study of continuous-current dynamo machinery. The author has endeavored to make use of as little mathematics as possible, results and inferences being discussed in connection with curves obtained in the experiments. The object throughout has been to encourage the student to carry out actual measurements on machines rather than to trust to calculations or formulas. The descriptions of experiments are intended for the use of students who are beginning the study of electrical machinery and for engineers who are only slightly acquainted with electrical work. The chapter headings are: General Purpose of Tests; Measurement of Armature and Field Resistances; Production of Electromotive Force in a Dynamo; The Magnetic Circuit; Armature Reaction; Shunt-Wound Dynamo; The Series Dynamo; The Compound Dynamo; Effect of Current in the Motor Armature; Efficiency Tests of a Motor; Efficiency Tests of a Dynamo; Miscellaneous Tests; Motor Generators and Boosters. There is an index of three pages.

FIELD AND OFFICE TABLES SPECIALLY APPLICABLE TO RAILROADS.

By C. Frank Allen, M. Am. Soc. C. E. Leather, 7 x 4 ins., 5 + 293 pp. New York, Spon & Chamberlain, 1903. $2.00. (Donated by the Author.)

Among the tables in this book are those for easement curves and for earthwork computation, several of which, the author believes, are new. These include the "Cubic Spiral" easement curve, which is arranged for a uniform chord length of 30 feet, and which gives all deflection angles for a large variety of spirals; also the "Offsets from Tangent for a 10° Curve" and "Angles Proportionate to Squares of Distances" are applicable to easement curves, but should be found useful for other purposes. There are also tables for Earthwork Computation. Those for regular three-level sections and for prismoidal correction are based upon tables used for computing the earthwork on many hundred miles on a prominent western railroad, and that for triangular prisms is similar in principle to that for prismoidal correction. Other tables for field use are: "Acres for Strip 100 Feet Wide," "Metric Curves," "Velocity Heights," "Mean Refractions in Declination" and "Stadia Reduction Tables." The table for "Tangent Distances for a 1° Curve" gives values for every minute up to 96°. Fourteen pages are devoted to the explanation of the tables.

RAILROAD CURVES AND EARTHWORK.

By C. Frank Allen, M. Am. Soc. C. E. Third Edition. Leather, 7 x 4 ins., 13 + 198 pp. New York, Spon & Chamberlain, 1903. $2.00. (Donated by the Author.)

The preface states that this book was written especially to meet the needs of students in engineering colleges, but it is hoped that it will be found useful by many engineers in actual practice. In the present edition the chapter on the Spiral Easement Curve has been entirely rewritten and enlarged. Two pages have been added to the chapter on Special Problems on Earthwork. The references to tables have been changed so as to apply to the newly published Tables. The chapter headings are: Reconnoissance; Preliminary Survey; Location Survey; Simple Curves; Compound Curves; Reversed Curves; Parabolic Curves; Turnouts; "Y" Tracks and Crossings; Cubic Spiral Easement Curve; Setting Stakes for Earthworks; Methods of Computing Earthwork; Special Problems in Earthwork; Earthwork Tables; Earthwork Diagrams; Haul; Mass Diagram; Tables and Diagrams.

COMPRESSED AIR.

A Treatise on the Theory and Practice of Pneumatic Power Transmission. By William Charles Popplewell, Assoc. M. Inst. C. E. Cloth. 9 x 6 ins., 8 + 284 + 3 pp., illus. Manchester, The Scientific Publishing Company. 7 shillings 6 pence, net.

The author does not claim that his work is exhaustive, but he has made an endeavor to discuss some of the chief points in the problems connected with the compression and transmission of air, and trusts that his notes on the principal features in current practice will prove of service to students as well as to practical engineers responsible for the maintenance and equipment of compressed-air installations. The Contents are: Introductory; General Principles of Pneumatic Transmission of Power; Air

Compressors; Ingersoll-Sargent Air Compressors; West & Jenkin's Air Compressors; Air-Controlled Rotary Valves; Air Motors; Appliances and Tools Worked by Compressed Air; Reciprocating Tools; Pneumatic Pumping Appliances; Pipes and Accessories Used in the Transmission of Power by Compressed Air; Compressed Air Calculations; Efficiency Tests of Compressed Air Machinery; Diagrams from a Single-Acting Two-Stage Compressor; Power Transmission. There is an index of three pages.

GEWÖLBESCHMUCK IM RÖMISCHEN ALTERTUM.

Studien und Aufnahmen. Von Konstantin Ronczewski. Herausgegeben vom Verfasser. Paper, 13 x 9 ins., 46 pp., illus. Georg Reimer, Berlin, 1903. 12 marks.

In this work the author has attempted to give a description of the most important antique vault decorations, with special attention to the various styles of ornamentation. The illustrations accompanying the volume are largely reproductions of works in Rome and Pompeii and are intended to supplement the short descriptions. The Contents are: Allgemeines; Kassetierte Gewölbe; Stuckdekorationen an Tonnen- und Kreuzgewölben; Plastische Dekorationen sphärischer Gewölbeflächen; Gemalte Dekorationen cylindrischer Gewölbe; Dekoration sphärischer Gewölbe mit Malerei und Mosaik; Schluss.

JAHRBUCH FÜR DAS EISENHÜTTENWESEN.

(Ergänzung zu *Stahl und Eisen.*) Ein Bericht über die Fortschritte auf allen Gebieten des Eisenhüttenwesens im Jahre 1901. Im Auftrage des Vereins deutcher Eisenhüttenleute bearbeitet von Otto Vogel. II. Jahrgang. Cloth, 10 x 6 ins., 16 + 464 pp., illus. Düsseldorf, A. Bagel, 1903. 10 marks.

This Yearbook is intended to serve as a supplement to the periodical *Stahl und Eisen* and to the *Gemeinfassliche Darstellung des Eisenhüttenwesens*, published by the Verein deutscher Eisenhüttenleute. It is a classified, annotated index to both German and foreign periodical literature treating of the metallurgy of iron. The subjects indexed are: Brennstoffe; Feuerungen; Feuerfestes Material; Schlacken; Erze; Werksanlagen; Roheisenerzeugung; Giessereiwesen; Erzeugung des schmiedbaren Eisens; Verarbeitung des schmiedbaren Eisens; Weiterverarbeitung des Eisens; Eigenschaften des Eisens; Legierungen und Verbindungen des Eisens; Materialprüfung.

Gifts have also been received from the following:

Akron, Ohio—City Engr. 1 vol.
Alaska Treadwell Gold Min. Co. 2 pam.
Am. Inst. Min. Engrs. 1 bound vol.
Am. Soc. Mech. Engrs. 1 pam.
Argentine Republic—Dirección de Vía de Communicación. 1 vol.
Atchison, Topeka & Santa Fe Ry. Co. 1 pam.
Atlanta, Ga.—Board of Health. 2 pam.
Bensel, J. A. 4 pam.
Berlin Technische Hochschule. 1 pam.
Binghamton, N. Y.—Board of Health. 3 pam.
Boston & Maine R. R. Co. 1 pam.
Bradley, C. W. 1 pam.
Canada—Dept. of Inland Revenue. 7 bound vol., 44 vol., 64 pam.
Chesapeake & Ohio Ry. Co. 2 pam.
Chicago Great Western Ry. Co. 1 pam.
City Record. 2 bound vol.
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Grundriss der Electrotechnik für den praktischen Gebrauch, für Studierende der Electrotechnik und zum Selbstudium. Von Heinrich Kratzert. 2. Auflage. Vol. 1, Pt. 1. Leipzig und Wien, Frank Deuticke, 1899.

Gas Engines and Their Troubles. By E. W. Roberts. With Additional Chapters on Design, Construction, Powering and Propulsion of Launches, by W. F. Durand. New York, Marine Engineering.

The Design and Equipment of Blast Furnaces. By John L. Stevenson. Published by the Author, London, 1902.

Devis et Évaluations. Par Émile Dardart et Auguste Bonnal. Paris, Vve. Ch. Dunod, 1903.

Spon's Engineers' Price Book. A Synopsis of Current Prices and Rates for Engineering Materials and Products, Alphabetically Arranged in Tabular Form, with Lists of Standard Sizes and Extras Chargeable; together with Data Required to be Sent when Ordering, also a Comprehensive and Concise Directory . . . of the Best Makers Arranged in Alphabetical Order. By Thomas G. Marlow. London, E. & F. N. Spon, Ltd.; New York, Spon & Chamberlain, 1903–4.

Les Pompes. Par R. Masse. Préface de Haton de la Goupillière. Paris, Vve. Ch. Dunod, 1903.

The Canal System of England: Its Growth and Present Condition, with Particular Reference to the Cheap Carriage of Goods. By H. Gordon Thompson. London, T. Fisher Unwin.

SUMMARY OF ACCESSIONS.

September 9th to October 13th, 1903.

Donations (including 26 duplicates)	380
By Purchase	7
Total	387

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ADDITIONS.

	Date of Membership.
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Burdett, Frederick Anderson. Cons. Engr., 3 East 33d St., New York City.	Jun. Feb. 2, 1897 Assoc. M. June 1, 1898 M. Oct. 7, 1903
Butts, Edward Pontany. Chf. Engr., Am. Writing Paper Co., Holyoke, Mass. (Res., Springfield, Mass.)	Assoc. M. Feb. 2, 1898 M. Oct. 7, 1903
Carr, Albert. Engr., First Div., Rapid Transit Comm., 13 Astor Pl., New York City (Res., 68 Carnegie Ave., East Orange, N. J.)	Assoc. M. Mar. 2, 1892 M. Oct. 7, 1903
Cole, William Weeden. Vice-Pres. and Gen. Mgr., Elmira Water, Light & R. R. Co., Realty Bldg., Elmira, N. Y.	Oct. 7, 1903
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Hardaway, Benjamin Hurt. Gen. Contr., Columbus, Ga.	Oct. 7, 1903
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Marston, Anson. Cons. Engr.; Prof. of Civ. Eng., Iowa State Coll., Ames, Iowa	Assoc. M. Oct. 4, 1893 M. Oct. 7, 1903
Poland, William Babcock. Supt., Indiana Div., B. & O. S. W. R. R., Cincinnati, Ohio.	Jun. Oct. 31, 1893 Assoc. M. May 3, 1899 M. Sept. 2, 1903
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Taylor, Selwyn Mellon. House Bldg., Pittsburg, Pa.	Oct. 7, 1903
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WILSON, WILLIAM EDWARD.....Asst. Prof. of Civ. Eng., Univ. of Utah, 326 C St., Salt Lake City, Utah.

DEATHS.

CUSHING, ROBERT DELANO.....Elected Associate Member, September 6th, 1899; died August 23d, 1903.
PATTERSON, JOHN AUSTIN.....Elected Member, May 2d, 1900; died May 3d, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(September 9th to October 13th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
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(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
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(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London England.

LIST OF ARTICLES.

Bridge.

The Mississippi River Bridges: Historical and Descriptive Sketch of the Bridges over the Mississippi River. F. B. Maltby. (4) Aug.
A Great Ferry Bridge.* (12) Aug. 28.
A Model Bridge and Construction Shop: Pennsylvania Steel Company's New Plant.* (20) Serial beginning Sept. 10; (14) Serial beginning Sept. 26.
The Viaur Viaduct on the Railway Line from Carmaux to Rodez, France.* René Bonnin. (13) Sept. 10.
Connel Ferry Railway Bridge.* (12) Sept. 11.
Engineering Aspects of the Kansas Floods.* Waddell & Hedrick. (14) Sept. 12; (13) Sept. 17; (15) Sept. 18.
Erection of the Girna Bridge, India.* (12) Serial beginning Sept. 25.
The Marietta Long-Span Highway Bridge.* (14) Serial beginning Sept. 26.
The Substructure of the Mingo Bridge over the Ohio River.* (14) Oct. 3.
The Method of Manufacturing the Large Eye-Bars for the Thebes Bridge. P. S. Hildreth. (13) Oct. 8.
The Pennsylvania Railroad Bridge over the Raritan River, at New Brunswick, N. J.* (14) Oct. 10.
The Ashland Avenue Bascule Bridge, Chicago.* (14) Oct. 10.
Note sur les Pièces Chargées de Bout Présentant Plus de Deux Points Fixés. F. Keelhoff. (31) Pt. 2, 1903.
Pont en Béton, sur le Neckar, près de Neckarhausen (Hohenzollern).* (35) Sept.
Passerelle en Béton Armé sur le Canal du Midi à Toulouse.* G. Espitallier. (33) Sept. 5.
Le Déplacement de la Passerelle de Passy sur la Seine, à Paris.* J. Feugères. (33) Sept. 19.

Electrical.

A High-Voltage Power Transmission.* M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E. (54) Vol. 50.
The Calculator Board and Graphic Methods (electrical localization of faults in submarine cables).* (26) Aug. 28.
An Oil Engine Central Station.* Howard S. Knowlton. (26) Aug. 28.
Design for 1 H.-P. Self-Starting Single-Phase Induction Motor.* (Reprinted from the *American Electrician.*) (47) Aug. 29.
The Induction Motor and Its Engineering Capabilities.* George L. Hoxie. (3) Serial beginning Sept.
The Otis Elevator Company's Electric Elevator for Private Residences.* (Report of the Committee on Science and the Arts of the Franklin Inst.) (3) Sept.
Electric Lighting and Traction at Southend-on-Sea.* (26) Sept. 4.
On a New Method of Tuning Wireless Telegraph Stations by Means of the "Multiplier."* Count Arco. (26) Serial beginning Sept. 4.
The West Penn Railways and Lighting System.* (17) Sept. 5.
Central Avenue Power Station, Kansas City, Kan.* H. S. Badger and G. E. Schreiber. (27) Sept. 5.
Electrical Transmission from Boston. (27) Sept. 5.
Rise of Efficiency in Electric Stations. Alton D. Adams. (27) Sept. 5.
Isolated Plant *vs.* Central Stations Supply of Electricity: A Suggestion for Obtaining Estimates of Costs on a Competitive Basis. R. S. Hale. (27) Sept. 5.
An Object Lesson in Telephone Receivers.* Arthur V. Abbott. (27) Serial beginning Sept. 5.
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Sand Washers at the Roxborough Filters, Philadelphia.* (14) Oct. 10.

Waterways.

The Economic Improvement of the Coosa and Alabama Rivers, in Georgia and Alabama.* D. M. Andrews, M. Am. Soc. C. E. (54) Vol. 50.
The Development of the Commerce of the Great Lakes. (Presidential Address at the Annual Convention of the Amer. Soc. of Civ. Engrs.) Alfred Noble, Pres. Am. Soc. C. E. (54) Vol. 50.
The Panama Canal.* George S. Morison, M. Am. Soc. C. E. (54) Vol. 50.
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Drague Marine Porteuse et á Refoulement pour les Ports de la Régence de Tunis.* Ch. Dantin. (33) Aug. 29.

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* Illustrated.

Vol. XXIX. OCTOBER, 1903. No. 8.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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A DESIRABLE METHOD OF DREDGING CHANNELS THROUGH RIVER BARS.

By S. Maximoff, Assoc. M. Am. Soc. C. E.

To be Presented December 2d, 1903.

The improvement of rivers by dredging is now being done on a large scale in Russia, and even a small improvement in dredging processes would result in an appreciable saving of money.

Before entering into any details regarding the writer's proposed method, he believes it necessary to give a short description of the present conditions of river navigation in Russia and of the Government's dredging fleet.

Russian River Fleet.

The last census of the Russian river fleet, taken in 1900, registered 26 154 boats and 35 000 miles of navigable waterways in European Russia.

Compared with the fleets of other countries, the tonnage is represented by the figures in Table No. 1, published recently by Mr. Lebedeff.*

* *Journal* of the Ministry of Ways of Communication, 1903, V.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

FIG. 1.

GROWTH OF THE RIVER-TOWED CRAFT IN EUROPEAN RUSSIA FROM 1882 TO 1900, (FINLAND NOT INCLUDED).

GROWTH OF THE RIVER STEAM FLEET IN EUROPEAN RUSSIA FROM 1815 TO 1900. (FINLAND NOT INCLUDED.)

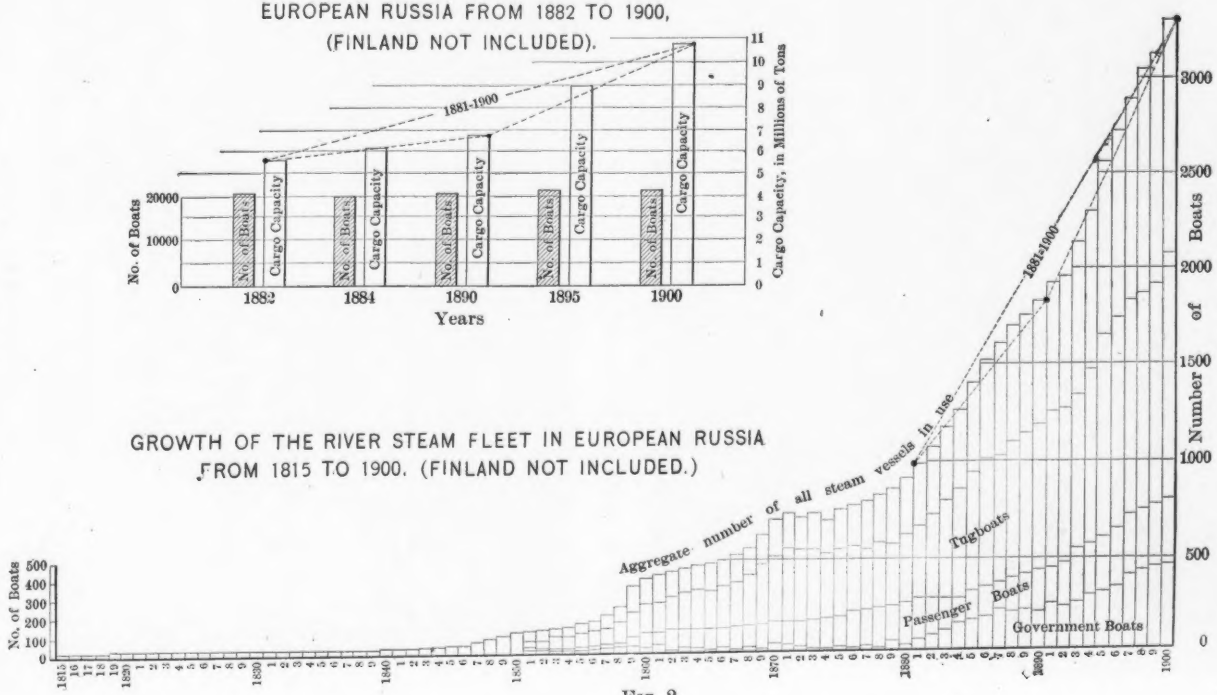


FIG. 2.

TABLE No. 1.

Years.	Fleet, and Country.	Metric tons.
1900	River fleet, European Russia	11 180 562
1900	Marine fleet, Great Britain	10 751 392
1897	River fleet, Germany	3 427 201
1900	Marine fleet, Germany	1 737 798
1892	River fleet. France	2 966 230
1900	Marine fleet, France	957 756

Classified by the material of construction, river boats are distributed as shown in Table No. 2.

TABLE No. 2.

	Iron.	Wood.	Total.
Steamboats	2 872	423	3 295
Towed boats	329	22 530	22 859

The growth of the number and of the freight tonnage of the towed fleet is represented by the figures in Table No. 3.

TABLE No. 3.

Year.	Number of vessels.	Cargo capacity, in metric tons.
1884	20 095	5 932 536
1890	20 125	6 572 727
1895	20 580	8 631 646
1901	22 859	11 044 094

This growth is represented graphically by Fig. 1.

The capital invested in towed boats amounts to $36 000 000, and the annual cost of building new boats of this kind is nearly $4 000 000. The average cost of a towed barge is $1 400, and there are 1 375 barges costing more than $5 000 each.

By single river basins, the barges are distributed as shown in Table No. 4.

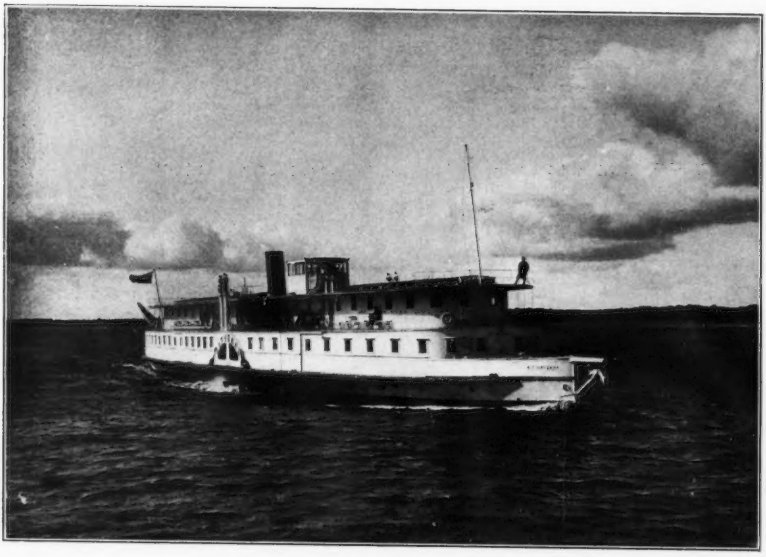


FIG. 1.—A TYPICAL RUSSIAN PASSENGER STEAMBOAT.

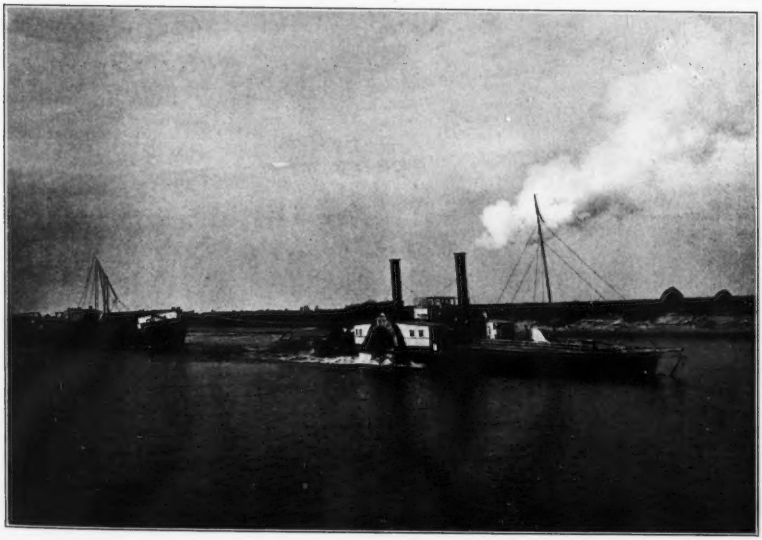


FIG. 2.—A TYPICAL RUSSIAN TUGBOAT.

TABLE No. 4.

No.	Length of waterways, in miles.	Basins.	Number of barges.	Cargo capacity, in metric tons.
1.....	16 260	Volga.....	8 250	7 215 296
2.....	2 570	Neva, with lakes and canals.....	7 645	2 604 869
3.....	4 610	Dnieper, with South Boog.....	2 205	509 217
4.....	3 900	North Dwina.....	1 210	273 059
5.....	2 490	Don.....	488	202 116
6.....	1 290	West Dwina.....	1 041	69 814
7.....	1 360	Vistula (in Russia only).....	514	65 305
8.....	4 860	Other rivers.....	1 506	104 418
Totals..	37 340	.....	22 859	11 044 094

The cost of the steam fleet is nearly equal to $64 000 000, and the annual cost of building new steamboats amounts to $4 500 000.

The growth of the steam fleet is represented graphically by Fig. 2.

The steam vessels are distributed by single river basins as shown in Table No. 5.

TABLE No. 5.

No.	Basins.	Number of steam-boats.	Total horse-power.	Average horse-power per boat.
1.....	Volga.....	1 718	440 019	256
2.....	Don.....	189	43 899	213
6.....	West Dwina.....	167	36 061	212
3.....	Dnieper, with South Boog.....	356	66 751	179
4.....	North Dwina.....	174	25 448	134
7.....	Vistula (in Russia only).....	50	5 022	91
2.....	Neva, with lakes and canals.....	525	59 499	87
8.....	Other rivers.....	116	10 084	87
	Totals.....	3 295	686 783	.....

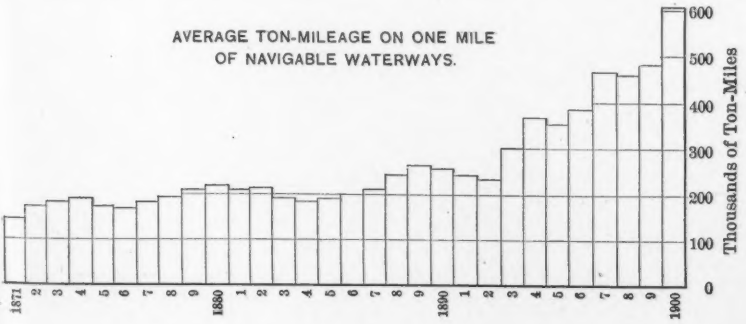


FIG. 3.

The total freight capacity of these steamboats is about 1 000 000 tons.

The largest steam vessel on the Volga is the towboat, *Rededia, Prince Cassogski*, developing about 2 000 H. P., and capable of towing 16 000 tons of freight up stream.

A typical passenger steamboat is shown in Fig. 1, Plate LIII. A typical tugboat is shown in Fig. 2, Plate LIII.

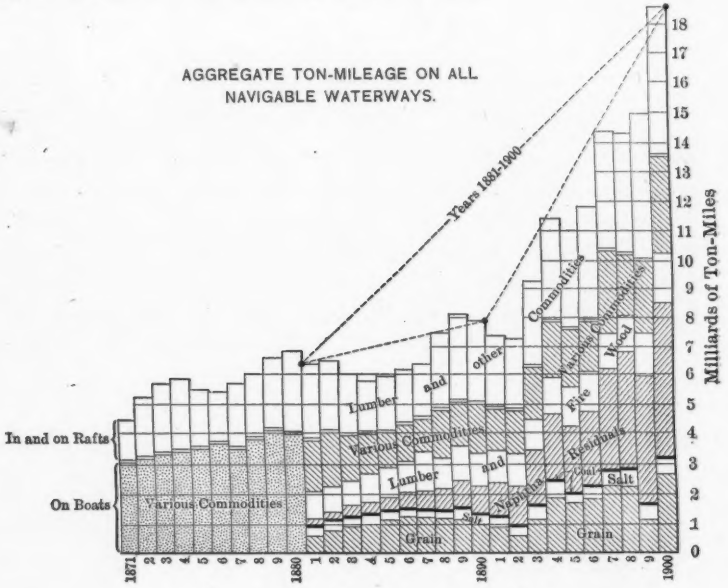
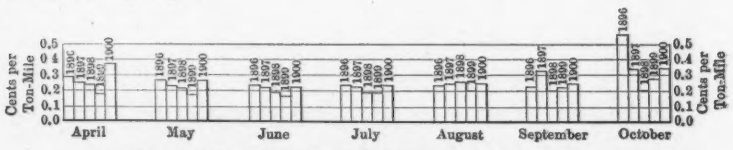


FIG. 4.

The amount of freight transported in 1900 was 600 000 tons per mile of navigable waterways (shown by Fig. 3), and the total number of ton-miles amounted to 18 600 000 000 (see Fig. 4). The rates of transportation for grain, the chief freight transported on the Volga, are shown by Fig. 5.



AVERAGE FREIGHT RATES ON THE VOLGA, TOWING UP-STREAM, FOR GRAIN TRANSPORTAION, IN CENTS PER TON-MILE.

FIG. 5.

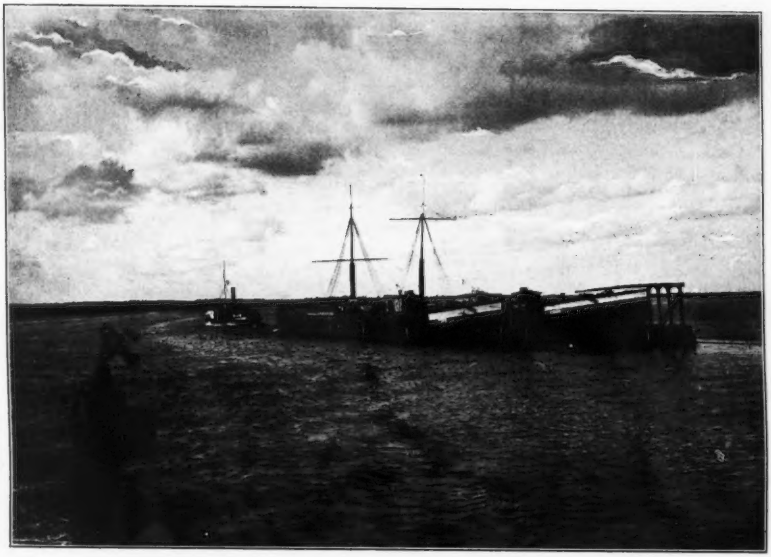


FIG. 1.—TYPICAL WOODEN BARGES ON RUSSIAN RIVERS.



FIG. 2.—A RUSSIAN "BIELANA."

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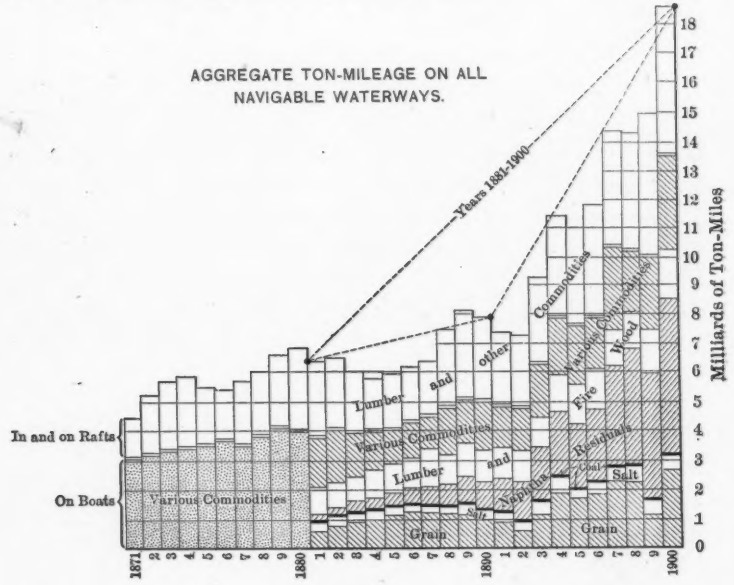
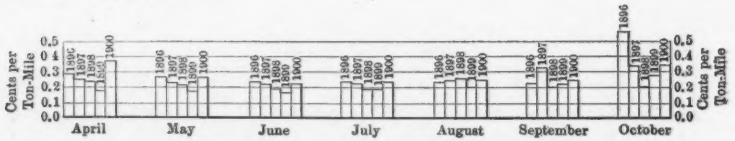


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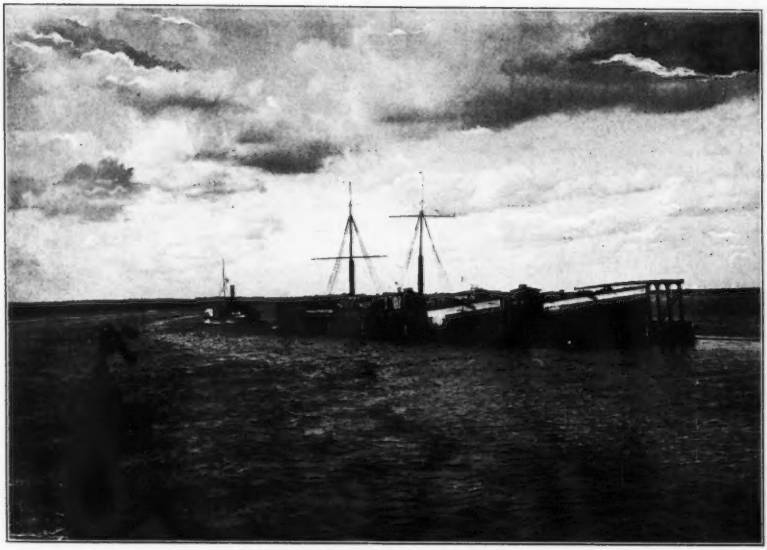


FIG. 1.—TYPICAL WOODEN BARGES ON RUSSIAN RIVERS.



FIG. 2.—A RUSSIAN "BIELANA."

The great progress of the water-transportation business is somewhat astonishing, when the natural conditions of Russian waterways are considered.

The Volga.

A brief statement of the physical data concerning the greatest European river, the Volga, will give a fair idea of the difficulties and obstructions to navigation.

The most important part of this river for transportation is that part between Rybinsk and Astrakhan, which can be divided into three districts.

District I.—Rybinsk to Nijni-Novgorod.—The total fall in this district is about 70 ft., distributed over a length of 296 miles.

High water rises to an average of 38 to 42 ft. above the lowest water stage, lasts nearly seventy days, and reaches the maximum at the end of April (old style). The lowest water stage arrives usually at the end of August.

The minimum discharge at low-water stage near Rybinsk is not less than 7 000 cu. ft., being generally about 15 000 cu. ft. at the end of that river district, *i. e.*, not far above the mouth of the Oka. During high water the discharge increases to 223 000 cu. ft.

The width of the summer bed of the river varies from 900 to 3 600 ft.

The depth of the pools is sometimes about 42 ft.

There are more than one hundred bars and other obstructions to navigation, and the minimum depth observed thereon during the last twenty years varies from 28 to 63 ins. But, at the same time, not more than twenty bars are dangerous for boats.

Barges in this district are from 70 to 350 ft. long, and more than 40% of the boats are longer than 280 ft. The draft of loaded boats is from 28 to 120 ins.

District II.—Nijni-Novgorod to the Mouth of the Kama.—The total length of this district is 297 miles, and the total fall about 84 ft.

The minimum discharge below the mouth of the Oka is nearly 26 000 cu. ft., and above the mouth of the Kama about 52 000 cu. ft. The maximum discharge amounts to 350 000 cu. ft.

The high-water stage lasts almost eighty-five days, and the water rises to an average height of 42 ft.

The number of bars and other obstructions amounts to seventy, and their minimum depth varies from 28 to 84 ins.

The pools at low water may be as deep as 56 ft.

The width of the summer bed of the river is from 1 000 to 3 750 ft.

Barges, here, are from 70 to 420 ft. long, and 40% of the boats are from 210 to 420 ft. long. The draft of 60% of the loaded boats is from 70 to 154 ins.

The cargo capacity of 30% of the barges exceeds 900 metric tons, and there are several barges carrying as much as 4 000 tons.

District III:—Kama to Astrakhan.—The length of this district is 1 060 miles. The fall from the mouth of the Kama to Tsaritsyn is about 165 ft.

The width of the summer bed varies from 1 750 to 5 600 ft., and sometimes reaches 9 000 ft.

The minimum flow is 113 000 cu. ft., the maximum (observed in 1884) is 1 426 000 cu. ft.

High water lasts about ninety days. It rises above the low-water stage as high as 50 ft. at the mouth of the Kama, or 12 ft. near Astrakhan.

The number of bars and other obstructions to navigation is about two hundred, and their minimum depth during the last twenty years has varied from 38 to 126 ins.

The barges, here, are from 70 to 350 ft. long, and their draft is from 28 to 140 ins. More than one-third of them draw more than 84 ins., and have a cargo capacity of nearly 3 200 tons each.

The foregoing data regarding the length and draft of towed boats refer to wooden barges—the chief freight boats on the Volga. Fig. 1, Plate LIV, is a photograph of some typical wooden barges.

The maximum freight capacity of a barge, as above stated, equals 4 000 tons; but all these barges are surpassed by the "bielanas," which are boats of special construction, moved by the current, and floated down stream. They are built only for one trip, carry lumber and freight, and are floated exclusively with spring high water. Fig. 2, Plate LIV, is a photograph of one of these "bielanas."

The average tonnage of these giant boats is 6 000 to 8 000 tons, and recently a mammoth one, of 13 000 tons, was built.

Fig. 6 represents the movement of freight on the Volga for the year 1900. It will be noted that a considerable part of the freight consists of rafts.

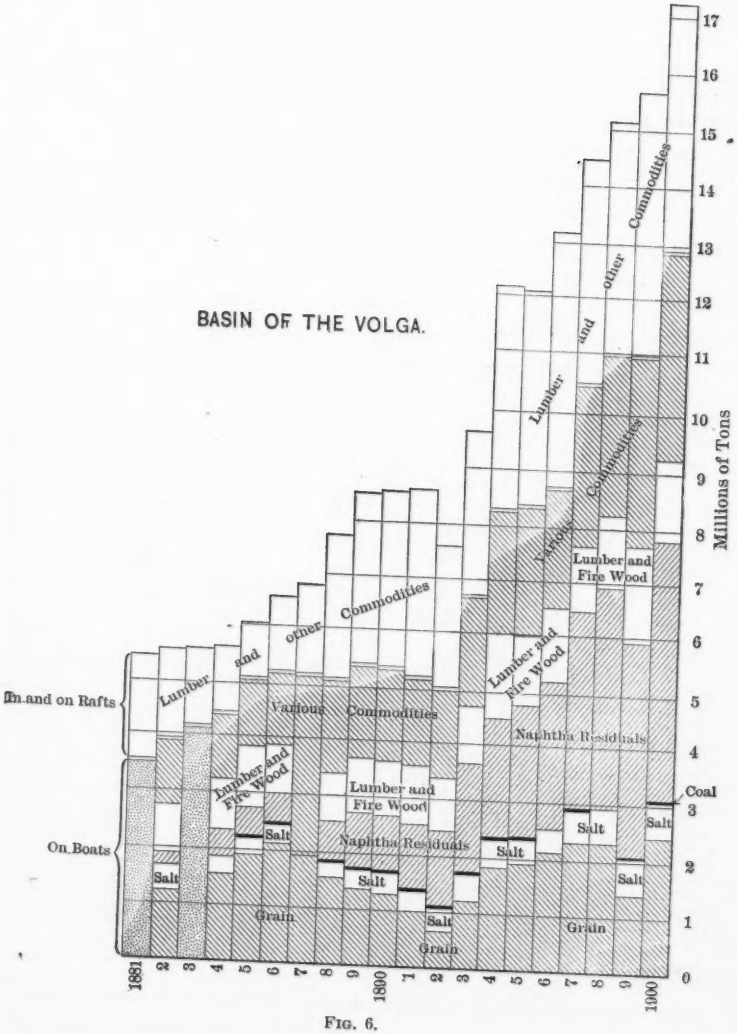

BASIN OF THE VOLGA.
Millions of Tons
In and on Rafts
On Boats
Lumber and other Commodities
Various Commodities
Lumber and Fire Wood
Naphtha Residuals
Salt
Grain
Coal
1881
1900

FIG. 6.

It should be remembered that the length of the period of navigation is only 6½ months. The duration of navigation and the boundaries of the river basins are shown by the map, Plate LV.

The Government's Dredging Fleet.

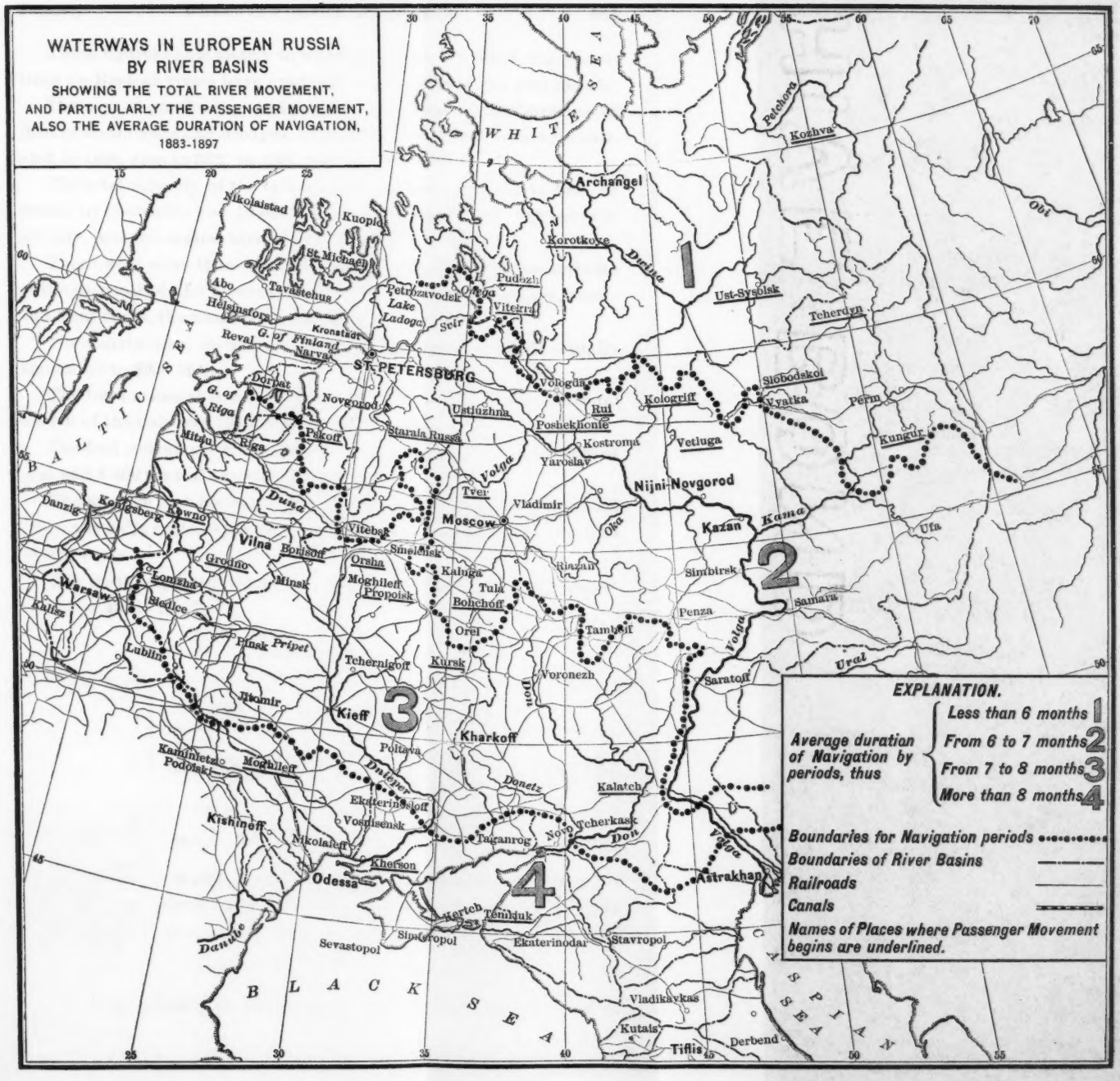
The marvelous progress of the water-transportation business called urgently for the improvement of the rivers, and this has been effected by permanent structures and by dredging.

Table No. 6 gives, approximately, the appropriations for maintaining and improving the natural and artificial waterways from 1886 to 1903, not including the expenses for central and permanent local administration.

TABLE No. 6.—Appropriations for Maintaining and Improving Natural and Artificial Waterways in Russia, from 1886 to 1903.

Years.	New works.	Great repairs.	Regular annual repairs.	Building, maintaining and operating Government steamboats and dredges.	Surveying rivers and lakes, and printing the results.	Totals.
1886.....	$714 581	$820 512	$467 944	$329 354	$129 743	$2 462 134
1887.....	531 546	820 512	513 476	235 992	148 351	2 249 877
1888.....	412 820	820 512	543 302	225 928	115 384	2 117 946
1889.....	1 035 593	846 153	579 193	221 231	85 128	2 767 298
1890.....	2 012 305	1 025 640	569 334	302 460	74 833	3 984 572
1891.....	2 278 330	1 025 640	871 794		76 841	4 252 605
1892.....	1 471 793	1 025 640	620 205	302 871	56 308	3 476 817
1893.....	1 957 434	974 358	923 076		56 728	3 911 596
1894.....	1 921 798	1 102 563	1 128 204		52 718	4 205 283
1895.....	1 644 101	1 025 640	1 241 379		88 718	3 999 838
1896.....	1 341 024	1 276 922	1 261 537		87 179	3 966 662
1897.....	1 864 416	1 405 127	1 389 742		74 359	4 733 644
1898.....	2 077 116	1 138 460	1 125 979	1 167 393	79 487	5 588 435
1899.....	1 946 817	1 575 835	1 198 674	1 174 204	79 487	5 975 018
1900.....	1 136 409	1 461 537	1 538 460	2 282 746	102 564	6 521 716
1901.....	576 922	1 312 295	1 551 024	1 910 152	102 564	5 452 957
1902.....	517 435	1 538 460	1 692 306	2 564 100	102 564	6 414 865
1903.....	448 718	1 692 306	1 846 152	2 564 100	102 564	6 653 840

In the column headed "New works" are included the expenses for the improvement of the Mary Canals (from the Volga to the Baltic Sea), amounting to $7 500 000; and for the construction of the Obi-Yenisei Canal, amounting to $400 000.


WATERWAYS IN EUROPEAN RUSSIA
BY RIVER BASINS
SHOWING THE TOTAL RIVER MOVEMENT,
AND PARTICULARLY THE PASSENGER MOVEMENT,
ALSO THE AVERAGE DURATION OF NAVIGATION,
1883-1897
WHITE SEA
BALTIC SEA
BLACK SEA
CASPIAN SEA
Archangel
Petchora
Kozhva
Obi
Korotkovo
Dwina
Pudozh
Onega
Lake Ladoga
Vitegra
Seir
Ust-Sysolsk
Teherdyn
Nikolaistad
Kuopio
St. Michael
Abo
Tavastehus
Helsingfors
Petrozavodsk
Kronstadt
Reval
G. of Finland
Narva
ST. PETERSBURG
Vologda
Slobodskoi
Vyatka
Perm
Kologriff
Dorpat
G. of Riga
Novgorod
Ustiuzhna
Rui
Poshekhonie
Kostroma
Vetluga
Kungur
Mitau
Riga
Pskoff
Staraia Russa
Volga
Yaroslav
Nijni-Novgorod
Danzig
Konigsberg
Kovno
Duna
Tver
Vladimir
Moscow
Oka
Kazan
Kama
Ufa
Vilna
Borisoff
Vitebsk
Smolensk
Grodno
Orsha
Kaluga
Riazan
Simbirsk
Warsaw
Lomzha
Minsk
Mogbilefi
Propoisk
Tula
Bohchoff
Penza
Samara
Kalisz
Siedlce
Orel
Tamboff
Lublin
Pinsk
Pripet
Tchernigoff
Kursk
Voronezh
Volga
Saratoff
Ural
Zhitomir
Kieff
Kharkoff
Poltava
Don
Kamieniec Podolski
Mogbilefi
Dnieper
Donetz
Kalatch
Ekaterinoslaff
Voznisensk
Kishineff
Nikolaieff
Taganrog
Tcherkask
Novo
Don
Volga
Kherson
Odessa
Astrakhan
Kertch
Temiuk
Danube
Sevastopol
Simferopol
Ekaterinodar
Stavropol
Vladikavkas
Kutais
Derbend
Tiflis
1
2
3
4
EXPLANATION.
Average duration of Navigation by periods, thus
Less than 6 months 1
From 6 to 7 months 2
From 7 to 8 months 3
More than 8 months 4
Boundaries for Navigation periods
Boundaries of River Basins
Railroads
Canals
Names of Places where Passenger Movement begins are underlined.



These figures show clearly to what an extent the dredging operations on Russian rivers have gradually grown during the past decade.

The cost of purchasing, maintaining and operating the Government fleet of steamboats and dredges, being 11% of the total sum appropriated in 1888, rose to 36% in 1901, and 39% in 1903.

The total capacity of the Government dredges operated in 1901, as stated by contracts, was 10 510 cu. m. per hour, their number was seventy, and the capital invested in them, $3 529 421.

There were more than one hundred and fifty inspection steamboats at the disposal of the Government engineers, towing dredges, scows and snag boats, the number of snag boats being seventy.

The maintaining, operating and repairing expenses in 1901 actually amounted to $908 864.

The total material dredged was 9 261 400 cu. yds., and the total length of the cuts was 768 215 ft., or 145.5 miles.

The fuel consumption was 20 000 tons of fire wood, 6 100 tons of coal and 8 400 tons of naphtha residuals.

The average cost per cubic yard of material excavated and carried away was 9 $\frac{81}{100}$ cents, while for single dredges it varied from 2 $\frac{70}{100}$ to 48 $\frac{40}{100}$ cents.

The most important dredging operations were on the Volga, as shown in Table No. 7.

TABLE No. 7.

	1899.			1900.			1901.		
	Total.	On the Volga.	Percentage.	Total.	On the Volga.	Percentage.	Total.	On the Volga.	Percentage.
Total length of the cuts, in miles.	56.9	15.4	36.9	80.1	34.9	43.6	145.5	54.2	37.3
Number of cubic yards, material excavated.	5 160 300	2 169 600	42.0	6 000 900	2 722 000	45.4	9 261 400	4 804 600	51.9
Money expended..	$516 487	$212 277	41.1	$590 700	$232 916	39.4	$908 864	$403 286	44.4
Average cost per cubic yard handled, in cents.	10 $\frac{1}{100}$	9 $\frac{75}{100}$	97.8	9 $\frac{84}{100}$	8 $\frac{56}{100}$	87.1	9 $\frac{81}{100}$	8 $\frac{30}{100}$	85.5

The data relating to the dredging craft on the Volga are given in Table No. 8.

TABLE No. 8 (*Continued.*)

DISTRICT II.—NIJNI-NOVGOROD TO MOUTH OF THE KAMA.

Desirable depth on bars, 70 ins.

7....	1893	*Volgian 1*	Ladder.	Scows and discharge pipe.	250	3.75	215	2.15	125	220	345	89 743	Hour capacity, 4 100 cu. m. Cost $942 761.
8....	1894	*Volgian 2*	"		250	3.75	215	2.15	125	220	345	89 743	
9....	1894	*Volgian 4*	"		250	3.75	215	2.15	125	220	345	71 468	
10....	1896	*Volgian 6*	Ladder and hydraulic suction.		250	4.75	215	2.50	125	250	375	92 883	
11....	1892	*Volgian 12*	Hydraulic suction.	Discharge pipe.	100	5.68	256	2.13	.....	.....	138	72 820	
12....	1899	*Volgian 7*	Hydraulic suction.		1 500	4.26	322.5	5.47	.....	.....	1 555	263 077	
13....	1899	*Volgian 8*	Hydraulic suction.		1 500	4.26	322.5	5.47	.....	.....	1 555	263 077	

DISTRICT III.—ON THE KAMA.

14....	1862	*Kamian 1*	Ladder.	Scows.	80	3.91	.....	.....	90	.....	90	35 897	Hour capacity, 80 cu. m. Cost $35 897.

DISTRICT IV.—NEAR SARATOF.

15....	1894	*Volgian 3*	Ladder and hydraulic suction.	Scows and discharge pipe.	250	3.75	215	2.15	125	220	345	72 972	Hour capacity, 500 cu. m. Cost $150 004.
16....	1896	*Volgian 5*			250	3.75	215	2.15	125	250	375	77 032	

DISTRICT V.—THE VOLGIAN DELTA.

17....	1879	*Volgian 16*	Ladder.	Scows.	40	3.50	.....	.....	170	.....	170	28 775	Hour capacity, 40 cu. m. Cost $28 775.

TABLE No. 8.

Data Relating to the Dredging Craft on the Volga.

District I.—Rybinsk to Nijni-Novgorod.

Number.	When built.	Name of dredge.	Mode of excavating material.	Mode of transporting material.	Contract hour capacity, cubic meters.	Depth of dredging, in meters.	Length of the discharge pipe, in meters.	Height of discharge, in meters.	Indicated Horse-Power.			Cost.	Total.
									Excavating machinery.	Centrifugal pumps.	Total.		
Desirable depth on bars, 56 ins.													
1....	1862	*Volgian 13*	Ladder.	Scows	30	3.20	.....	.....	40	.....	40	$23 077	
2....	1862	*Volgian 14*	"	"	35	3.20	.....	.....	75	.....	75	26 154	
3....	1862	*Volgian 15*	"	"	35	3.20	.....	.....	75	.....	75	26 154	
4....	1900	*Volgian 11*	Ladder and hydraulic suction.	Scows and discharge pipe.	150	4.25	320	4.26	75	200	275	76 923	Hour capacity, 750 cu. m. Cost $340 371.
5....	1900	*Volgian 9*	Ladder.	Scows and discharge pipe.	350	5.50	213	2.13	275	275	550	123 077	
6....	1900	*Volgian 10*	Hydraulic suction.	Discharge pipe.	150	3.00	200	2.13	.....	.....	180	64 986	

The total contract-hour capacity of the sixteen Volgian dredges is 5 390 cu. m., these dredges representing an investment of $1 461 900.

It should be stated that some dredges of District II usually work on District I in the beginning of the season, together with the dredges of the last-mentioned district, because the bars in District II commence to shoal later than those in District I.

During 1901 the dredges worked in depths varying from 1½ to 12 ft. The number of hours of effective work varied from 22.6% to 80.2% of the total number of hours in the season.

On an average, the dredges spent 56% of the working time on the bars, 22% in deepening the winter refuge harbors and 22% in towing, putting in place, in boiler cleaning and other delays and unproductive work.

The dredges on the Volga are mostly ladder dredges. A typical Volgian dredge is shown on Plate LVI, and drawings of the Ladder Dredge *Volgian 9th* are shown on Plate LVII.* They have shown very satisfactory results. The weak points are the want of power in the centrifugal pumps and the insufficient length of the floating discharge pipes. These faults are common to nearly all the dredges except the latest ones built, and will be remedied by reconstruction.

The expenses for dredging and for operating steamboats attached to the dredging craft on the Volga in 1901 amounted to $374 880. Most of the repairs of dredges and steamboats were made in the Government shops, the operating expenses of this kind amounting to $28 407. Adding this extra expenditure to the first mentioned gives $403 287, the total cost of dredging in 1901.

Assuming the amortization at the rate of 6%, the total capital invested in dredging appliances being, as above stated, $1 461 900, the annual cost of amortization will be $85 000.

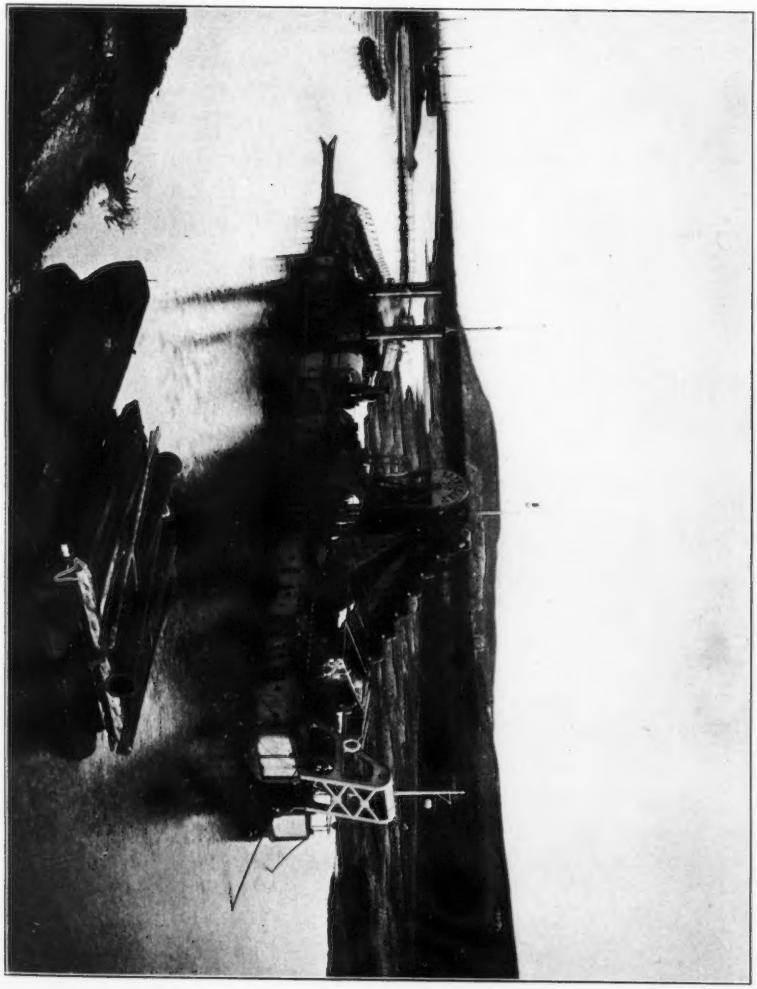
The deepening of winter refuge harbors in 1901 cost $118 000, as given by Mr. Vodarski.†

Thus, for the purpose of improving the water transportation, the sum of approximately $403 287 + 85 000 — 118 000 = $370 287 was spent.

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* This occasion is taken to acknowledge the courtesy of Mr. Ivanitski, Chief of the Waterways Department of the Ministry of Ways of Communication, who has enabled the writer to show an official drawing of the dredge *Volgian 9th*.

† *Proceedings* of the Annual Meetings of Persons Interested in Russian Waterways Development, 1902.



A TYPICAL RUSSIAN LADDER DREDGE.

This help to navigation is needed during low-water stage only, that is, in July, August and September.

The quantity of freight transported on the Volga between Nijni-Novgorod and the mouth of the Kama exceeds 7 000 000 metric tons, but the greater portion being carried in the spring, it is admitted, that only 1 500 000 metric tons of freight are benefited directly by the dredging, so that the cost of dredging per metric ton of freight benefited is $0.243.

At the same time, the freight rate for the transportation of naphtha residuals, for example, from Astrakhan to Nijni-Novgorod (1 357 miles), is nearly equal to $1.50 per ton. It is evident that calculations of this kind are only approximate. Nevertheless, they prove clearly that navigation receives substantial aid, even from such small appropriations.

Compared with the business done, the sums expended by the Government seem to be insignificant, but they are very great when compared with the freight rates, and cannot be increased further without careful consideration. On the other hand, the fact that the appropriations are small makes it necessary to use the existing dredging craft with the greatest care and economy.

This question of economy is still more important in view of the fact that shipowners eagerly call for a further increase of the dredging fleet.

The Problem of Dredging.

Considered from the most general point of view, the routine business of the dredging craft on rivers consists in creating an easy and deep waterway for boats, and in deepening entrances and areas of river harbors and winter refuges, all of which must be accomplished at a small cost.

To obtain this result, two things must be taken into consideration.

First, it is necessary that the dredging fleet be equipped and maneuvered with care and foresight.

Secondly, with the most modern and well-equipped plant in the world, the durability of the improvement obtained by dredging must not be lost sight of. This is a subject which has not been investigated sufficiently.

To accomplish the first requisite the efficiency of each individual dredge in one working hour must be the maximum, under given con-

ditions. Each dredge should be properly designed for the work to be performed, and its crew should be sufficient, but not superfluous.

The efficiency of each individual dredge during the whole working season should also be the maximum. As many hours as possible of the whole working period must be spent in excavating material and carrying it away, and idle hours, unproductive delays, towing dredges, cleaning boilers, etc., must be reduced to a minimum.

Besides this, the efficiency of the whole dredging plant must be the maximum. This means that the number of units and their capacity must be properly designed and combined; that the steamboat service be cheap enough; that the winter expenses be low; that the supervision be strongly enforced; and the accountability include all important details without being complicated.

It is not the purpose of the present short paper to explain how this service is now organized in Russia. Much has been done, in this respect, especially by Mr. Kleiber, the Second Engineer of the Dredging Department on the Volga, whose reports* have notably advanced the knowledge of this subject.

Proposed Scheme of Dredging.

It is important to find such a shape for the channel to be cut as will not only prevent any filling up, but insure its maintenance and even its scouring and deepening.

In discussing the proper shape for dredge cuts, the writer will use the data relating to the average conditions in the District of the Volga between Nijni-Novgorod and Kama. The dredge cuts on the Volga are now made as channels of constant width (250 to 260 ft.), and the depth of dropping the ladder remains constant during the whole of the operations, or is sometimes reduced at the rate at which the water level falls on the bar. To prevent a possible filling up of the dredged channel, an extra depth of 14 ins. is generally provided.

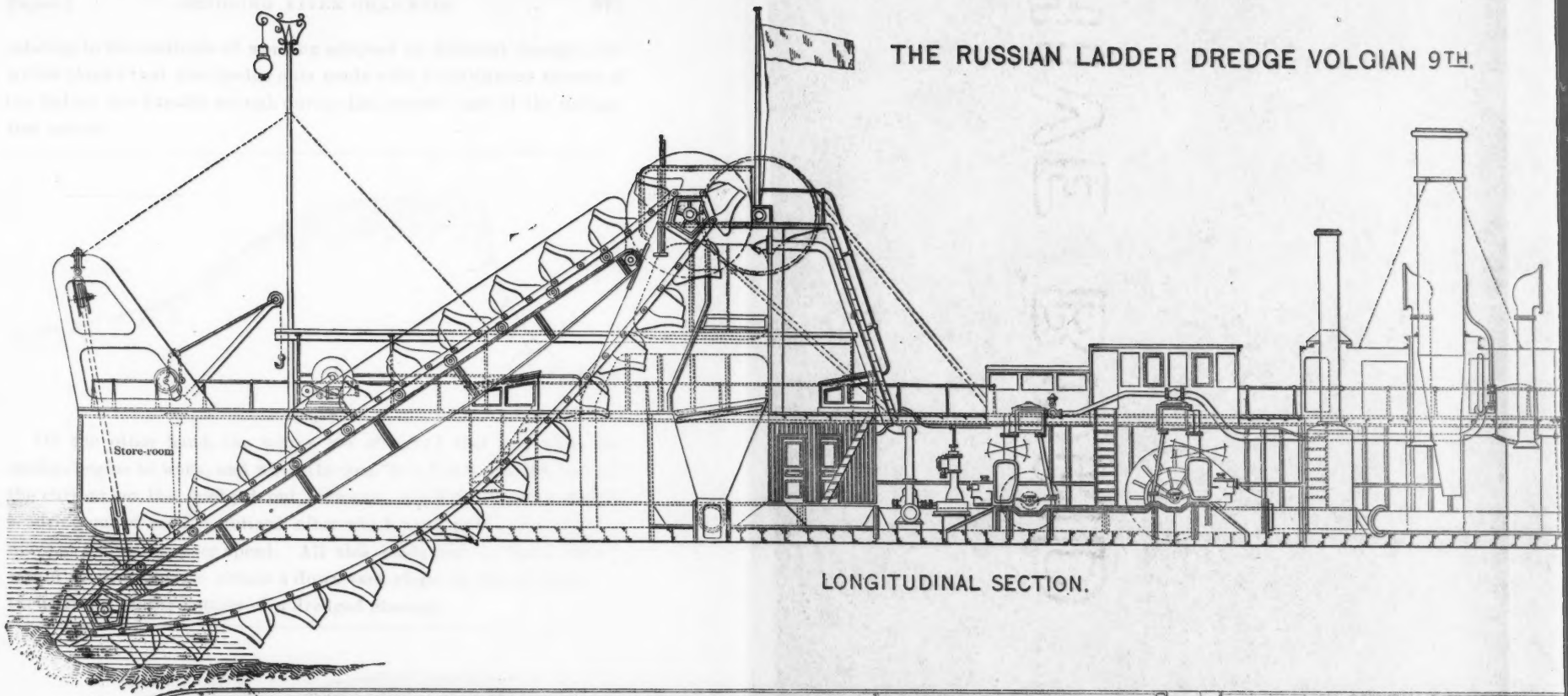
Both ways of dredging, *i. e.*, dropping the ladder to a constant depth, or raising it in proportion to the falling of the water level are left to the discretion of the dredge officers.

Although no special observations on the subject have been made, yet, according to officially published data† and special information

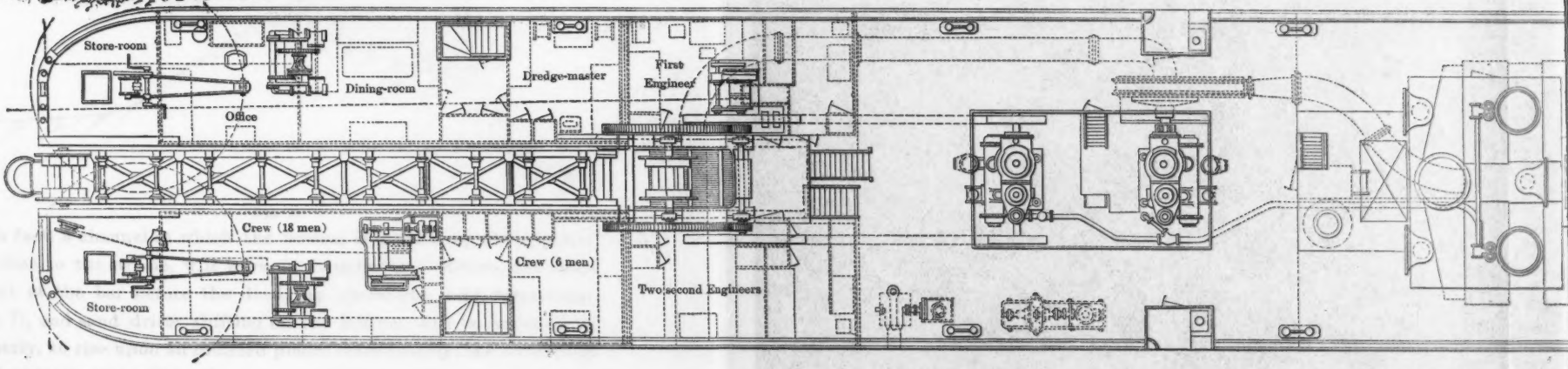
* See articles in the *Journal* of the Ministry of Ways of Communication; *Proceedings* of the Annual Meetings of Persons Interested in Waterways Development; and, also, other publications.

† *Supplements to Telegraphic Bulletins* of the District of Waterways in Kazan.

THE RUSSIAN LADDER DREDGE VOLGIAN 9TH.



LONGITUDINAL SECTION.



PLAN.

relating to the methods of working adopted on different dredges, the writer thinks that the dredge cuts made with a continuous raising of the ladder are durable enough during the greater part of the navigation season.

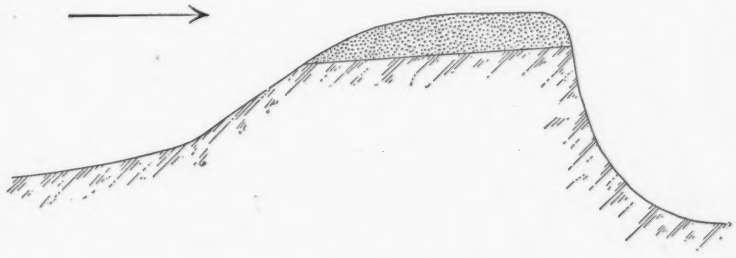


FIG. 7.

On the other hand, the writer has observed that just when the dredge begins to work, and when the first 70 to 100 ft. are left behind, the current on the dredged cut increases rapidly. Then a certain scouring out of sand is noticed, after which sand drifts commence to move at a much greater speed. All this leads him to think that it would be desirable to obtain a downward slope, in the direction of the current, on the bottom of a dredged channel.

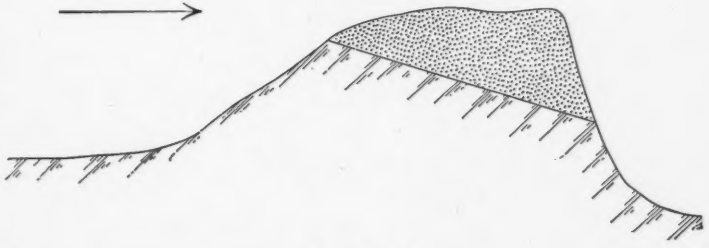


FIG. 8.

In fact, a channel in which the bottom is inclined in the opposite direction to the stream, will have, in longitudinal section, the same aspect at the bar before the dredging operations were commenced (Fig. 7), and sand drifts, shifting on the bottom, will be impelled, as formerly, to rise upon an inclined plane; consequently, the conditions of their movement will be the same as existed previously, and the bar will tend to the former shape of equilibrium.

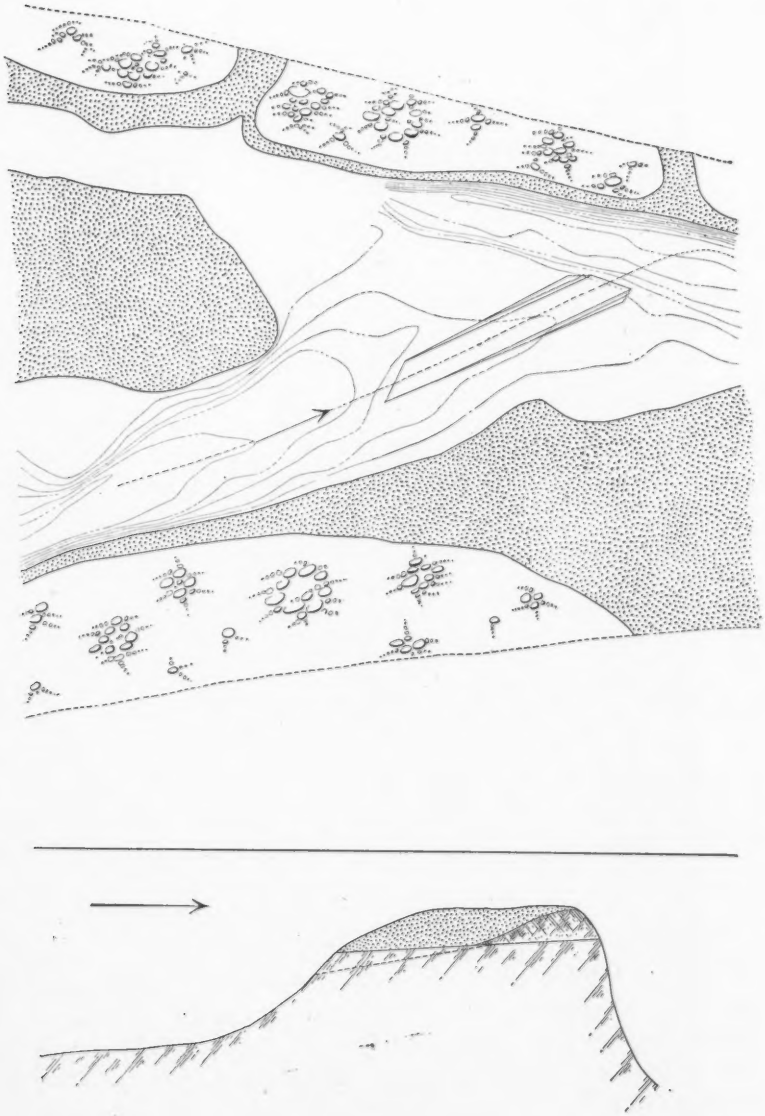


Fig. 9.

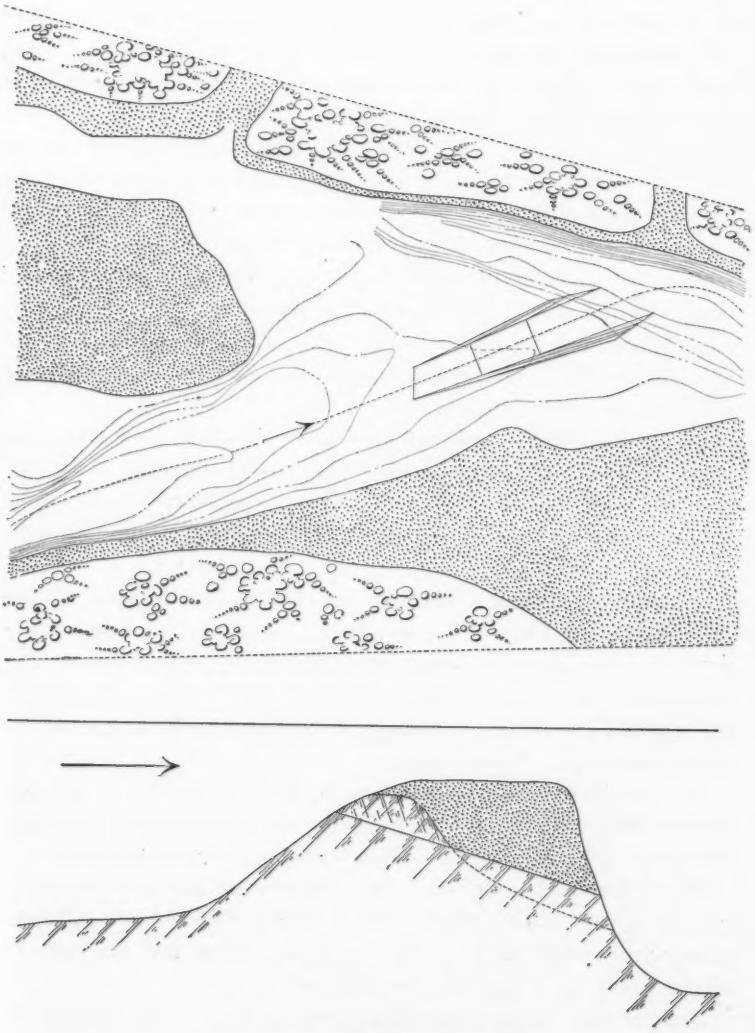


FIG. 10.

On the contrary, if the bottom of the dredged channel slopes downward in the direction of the current, the water need exert much less force in pushing the drifts down the inclined plane (Fig. 8).

It would seem, therefore, that in beginning the dredging (and moving against the current, as usual) it would be reasonable to drop the ladder as deep as the construction of the dredge permits, *i. e.*, 13 to 14 ft., and, after raising it gradually, finish the work at the depth required by navigation, *i. e.*, 70 ins. plus the height of water over its low stage. But this is not all that is necessary to ensure success.

From the examination of drawings showing dredged channels, it appears that these channels are commonly filled either from above or from below, while, in the middle, almost always, there remains some material which slowly disappears in the course of time.

It can be supposed that a dredged cut is filled at its down-stream end when its bottom is inclined against the current, *i. e.*, in such case the bar crest is most quickly restored (Fig. 9).

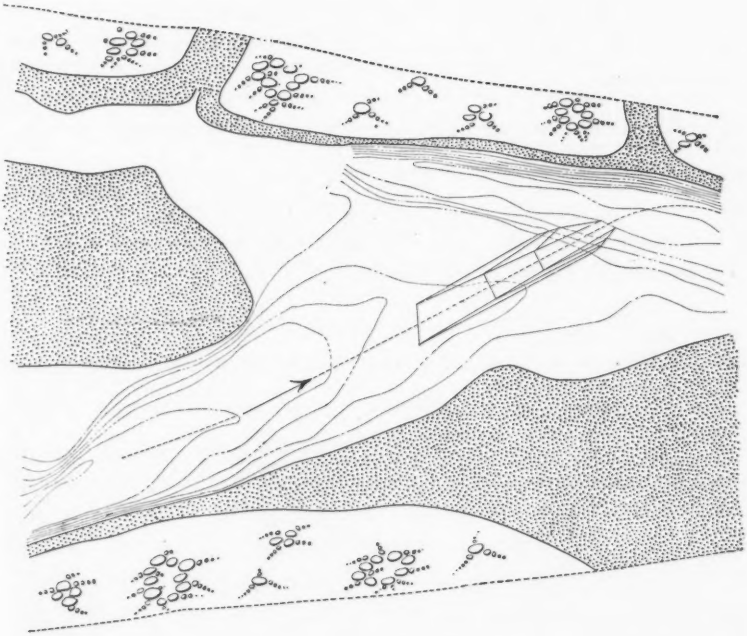
A dredged cut is probably filled at its up-stream end when it is made artificially with a downward slope in the direction of the current, or if its width at the up-stream end remains equal to or became smaller than the down-stream end (Fig. 10), such slope has been eroded by the current.

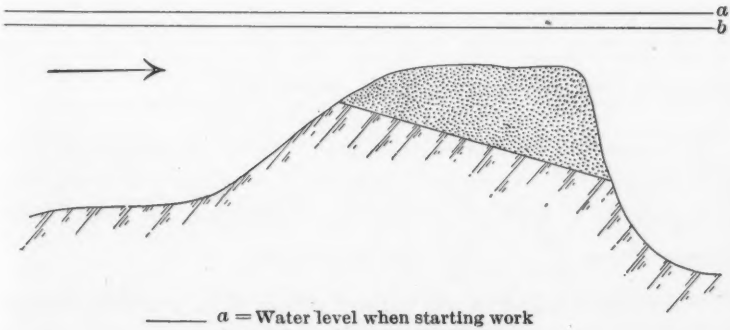
Therefore, a dredged channel should be commenced narrow, on the supposition that it will be scoured little by little, and, according to the rate of progress of this erosion, the width of the dredged cut should be increased, going up stream, so that the funnel-shaped opening of the channel into which the water is entering shall be constantly turned against the current (Fig. 11).

Briefly, the basis of this proposed method of dredging is the supposition that, owing to the shape herein recommended, the progress of the suspended material in a dredged channel will be the easier.

This suspended matter, and the particles of material excavated from the bottom and side slopes of the dredged channel itself, will pass along, without hindrance, to the deep water below, and the channel will be durable and possibly even deepened by scour.

Furthermore, on account of the forced erosion in the direction of the dredged cut during the progress of the work, there will be a constant reduction in the amount of cutting necessary, and the estimated total length of the cut will be reduced (Fig. 12), which is very im-





——— a = Water level when starting work
--------- b = " " " finishing "

FIG. 11.

portant, in view of the fact that the dredging plant will be utilized more fully.

This reasoning may now be applied to the practical data, supposing the dredging to have been commenced after the beginning of the low-water season.

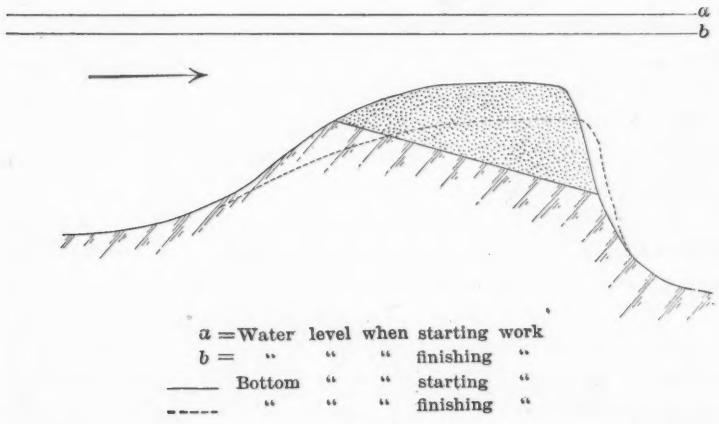


FIG. 12.

Suppose the mean length of the cut to be 1 650 ft. and the mean progress of the work to be 110 ft. a day, then the dredge will spend fifteen days in making the channel.

During that time the water will fall, roughly, from 1 to 2 ins. a day, which will make a total of 15 to 30 ins. $= F$.

Since the difference, D, between the highest and lowest positions of the ladder is $156 - 70 = 86$ ins., the fall, I, of the bottom, on the whole length of the cut, 1 650 ft., will measure

$$I = D - F = 71 \text{ to } 56 \text{ ins.}$$

This quantity is considerable in itself, but its importance becomes more evident if it is remembered that the slope of the water surface on a bar is only 1 in. to $1\frac{3}{4}$ ins. in 1 000 ft., consequently the slope of the bottom will be $\frac{56}{1650} : \frac{1\frac{3}{4}}{1000} = 20$ times more.

To give such a slope to the channel bottom it is necessary to raise the ladder from 71 : 15 to 56 : 15; that is, 5 to $3\frac{1}{2}$ ins. every day.

The width of the channel to be chosen beforehand can be determined approximately by supposing, for the first rough calculation,

that the channel will not be scoured, and that the width of its upper end must not exceed 325 ft.

Let it be supposed that the mean velocity in the lower end of the channel must not be less than that in the upper end, and that the same quantity of water that enters the channel must pass through it. Then the areas of the channel sections at both ends must be equal, and the width of the cut must be inversely proportional to its depth, *i. e.*, the width of the down-stream end will be $\frac{6 \times 325}{13} = 150$ ft., for which width the work must be laid out.

At the end of the first day, by such a calculation, the ladder would be dropped to 12 ft. 8 ins., and the width would be extended to $\frac{13 \times 150}{12\frac{2}{3}} = 154$ or 155 ft.

At the end of the second day the ladder would be dropped to 12 ft. 4 ins., and the width would be extended to $\frac{13 \times 150}{12\frac{1}{3}} = 158$ or 160 ft.

It may be thought, however, that it is necessary to provide a greater width, owing to scouring at the down-stream end of the cut, but it will not be difficult to make a new cut of greater width in case erosion does not take place as expected. In all cases it is desirable to which the results of the work during its progress, in order to determine in each case whether any modifications of the plan are necessary.

The rule to be observed is that each succeeding up-stream cross-section of the channel must be broader and shallower than each preceding down-stream cross-section.

During the progress of the work the down-stream cross-section may be eroded, and then the above-mentioned rule must be applied to the changed conditions.

There is one feature which is essential to the success of the proposed system of dredging to which attention should be especially called: During the operations the axis of the channel must make as acute an angle as possible with the mean direction of the current through the bar. The direction of the current can be determined by the plotting of the survey showing the contour lines.

Should the dredged channel be traced so that the current erodes only one side of the cut and causes drift to form on the other, no sure method of preventing the channel from filling up can be indicated. Circumstances may occur, under which the proposed shape

cannot be realized, but the writer believes that in every case, when possible, its adoption will prove justifiable.

The only objection to this method ever heard by the writer was that it would involve an extra expenditure by increasing the amount of excavation. But this would be offset by the greater stability of the dredged channel. It is believed that the increase of work would not be very great, because it is highly probable that the channel would be scoured by the current during the progress of the work. Questions of this kind can be solved only by experience.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

IMPERVIOUS CONCRETE.

An Informal Discussion at the Annual Convention, June 11th, 1903.*

SUBJECT FOR DISCUSSION:

"Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

BY SANFORD E. THOMPSON, Assoc. M. Am. Soc. C. E.

Mr. Thompson.

SANFORD E. THOMPSON, Assoc. M. Am. Soc. C. E. (by letter).—The writer's attention was first called to the possibility of making pure concrete of very thin section impervious to water, by a visit to the filtration works of the East Jersey Water Company, at Little Falls, N. J.,† through the courtesy of the Resident Engineer, William B. Fuller, M. Am. Soc. C. E. A circular wall of reinforced concrete, 15 ins. in thickness at the bottom, and withstanding, either upon the inside or the outside, a pressure of water of more than 40 ft. in depth without leakage, proves beyond question the possibility of laying concrete which is practically impermeable. Another example of concrete construction, at the same plant no less remarkable, in view of the difficulties usually encountered in placing a thin wall of reinforced concrete, is a circular tank, 4 ft. in diameter and holding water to a depth of 4 ft., with wall and bottom only 3 ins. thick.

The double-track tunnel between Boston and East Boston, built under the harbor by the Boston Transit Commission‡, Howard A.

* The discussion of this subject, on which no formal paper was presented, is continued from the September, 1903, *Proceedings*.

† See paper describing this plant, by George W. Fuller, Assoc. M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. L., p. 394; and discussion thereon by Mr. William B. Fuller, on p. 453.

‡ See Seventh Annual Report, Boston Transit Commission, 1901.

Mr. Thompson

Carson, M. Am. Soc. C. E., Chief Engineer, illustrates the construction, under difficult conditions, of concrete which could not be laid as a monolith, but had to be built in sections 30 ins. in length. The thickness of the arch and walls is 33 ins., and at high water the depth of the roof below the surface of the harbor may be as great as 70 ft. The writer observed, when walking through the tunnel soon after the air pressure was removed, that the only leakage consisted of percolations at the joints between the sections of concrete laid on different days. These emitted a scarcely appreciable volume of water, and were being closed by forcing in neat-cement grout under pressure.

It is generally agreed by engineers, in this country and abroad, who are accustomed to placing concrete which is to withstand the percolation of water, that the essential elements for impermeability are:

An aggregate (including sand) proportioned for great density;
An excess of cement;
A wet mixture carefully placed;
Monolithic construction.

The addition of foreign substances, such as soap and alum, slaked lime, or pozzuolana, has for its chief object the introduction of very finely divided matter into the pores of the concrete, and as long as the cohesion of the cement is not injured, it makes very little difference, as regards the permeability, whether their action is chemical or mechanical. A mechanical addition may actually increase the strength as well as the impermeability, simply by increasing the density, and, therefore, may replace a portion of the cement, which, as the finest ground material in ordinary concrete, must otherwise fill all the residual voids in the aggregate, with a surplus to provide for imperfect mixing. Clay has been suggested as a suitable ingredient for increasing the density, as laboratory tests tend to show that a small admixture of clay increases rather than diminishes the strength of mortars. While in the laboratory this might be proved effective, its use in the field would probably be impracticable because of the tendency of its particles to adhere, and form balls having slight cohesion.

M. Feret, in France, has recently been conducting a series of experiments* to determine the effects of mixing, by grinding together, materials of a pozzuolanic character with cement, to be used in sea water. Specimens in the air were injured by the introduction of this material, but those exposed to sea water were improved. By comparison with specimens to which had been added matter of the same fineness as the pozzuolana, but inert in character, the action is proved to be, at least in part, a chemical one, and the results not merely due to the greater density obtained by the more perfect filling of the voids.

The relation between porosity and permeability, which has been

* *Annales des Ponts et Chaussées*, 1901, Part IV, p. 195.

referred to by Mr. Lesley, is misleading. Although M. Alexandre, as quoted by M. Feret, shows that the more porous mortars are sometimes the less permeable, this principle cannot be applied strictly to concrete, because, in a porous concrete, as the term is generally accepted, the voids are apt to be of such size that the capillary action of the water contained in them is insignificant. One of M. Feret's most important deductions has a clear bearing upon this point: Mr. Thompson.

"It must not be understood, however, that the quantity of water which, under a given pressure, traverses a mortar during a given time is necessarily proportional to the total volume of voids in the mortar. It depends especially upon the size of the voids considered separately. Thus it is that if one compares a series of mortars obtained by combining equal weights of the same cement with sands of increasingly large dimensions, it is noted that the permeability may be very slight for the first and considerable for the following, although the real volume of solid material entering into the unit volume of the mortars goes on increasing at the same time with the size of the sand."*

Mortars made with fine sand, however, M. Feret states, although less permeable, are apt to be more easily acted upon by sea water. Considering, now, mixed sands, M. Alexander has shown by experiments that these are less permeable than either coarse or fine sifted sand alone, and Table No. 1, from his paper on Hydraulic Mortars† shows the results of his experiments with different sizes of screened sand, and also the effect of time, and of varying the proportion of cement to sand, upon the percolation of water through a thickness of 4 cm. of mortar.

TABLE No. 1.

Character of Mortar.				Time for 0.025 Liter of Water to Percolate under a Head of 0.50 m.		
Size of sand.		Quantity of cement per cubic meter of sand.	Proportions of cement to sand by weight.‡	At the beginning.	After one month.	After two months.
Passing screens with meshes per decimeter:‡	Corresponding to screens having meshes per linear inch:‡					
Coarse (25 to 45).	6½ to 11½	250 kgr.	1 : 5.4	Instantaneous.	Instantaneous.	1 minute.
		400	1 : 3.4	Instantaneous.	15 minutes.	24 hours.
		550	1 : 2.4	5 seconds.	24 hours.	.....
Fine (175 to 280).	45 to 72	250	1 : 5.4	45 seconds.	2 hours.	.....
		400	1 : 3.4	20 minutes.	5 hours.	.....
		550	1 : 2.4	45 minutes.	24 hours.	.....
Mixed equal parts (25 to 45) (45 to 60) (90 to 110) (140 to 175) (175 to 290).	Equal parts (6½ to 11½) (11½ to 15½) (23 to 28) (36 to 45) (45 to 72)	250	1 : 5.9	1 minute.	3 hours.	.....
		400	1 : 3.7	45 minutes.	30 hours.	.....
		550	1 : 2.7	3 hours.	Several days.	.....

* *Annales des Ponts et Chaussées*, 1892, Part II, p. 91.
† *Annales des Ponts et Chaussées*, 1890, Part II, p. 407.
Columns compiled by the writer from data given by Alexandre.

Mr. Thompson. The mixed sands undoubtedly reduce the size of the voids, and as at the same time they give greater density, they are consequently to be selected in preference to either the coarse or the fine. Extending this principle to the coarser materials of the aggregate in concrete, the conclusion is reached that the selection of materials to produce greatest impermeability coincides with the selection of materials for maximum strength, that is, the proportioning of the aggregate so that the grains of any one size will be sufficient in quantity to fill the voids of the larger sizes.

It is obvious that a mass containing voids or "pockets" such as we invariably see in concrete mixed with an exceedingly small percentage of water, and sometimes also in concrete mixed wet but laid carelessly so that the mortar is allowed to run away from the stones, is more permeable than a mixture which to the eye is dense and compact. In regard to the more minute voids the conclusion is not so clear, the advocates of dry-mixed concrete claiming that the surplus water when evaporating leaves voids which reduce the density of the mass. Mr. William B. Fuller, a champion of the wet mixture, has, on the other hand, asserted that, in his belief, the greater specific gravity of the solids causes them to expel the surplus water. Experiments, in collaboration with Frederick W. Taylor, M. E., which the writer now has under way, and which he hopes at a later date to present to the Society, tend to prove the correctness of Mr. Fuller's theory. Careful measurements of specimens, of both mortar and concrete, made with varying percentages of water, show, after setting, almost identical volumes, and, therefore, nearly equal density. A dry mixture, however, to bring it to this point, requires very violent ramming, harder than can be given in practical work, while the very wet mixtures need to be merely "joggled."

With the latter specimens, water, varying in amount with the quantity used in the mix, rises at once to the surface, and if the mould is tight and the solid materials are carefully proportioned, it may remain there until it evaporates, or until taken up by the capillary action of the mass.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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SOME RAILWAY CONSTRUCTION IN OKLAHOMA.

Discussion.*

By SAMUEL H. LEA, M. Am. Soc. C. E.

SAMUEL H. LEA, M. Am. Soc. C. E. (by letter).—This paper is of much interest, as it describes current engineering practice in railroad construction. In the writer's opinion, the method given for spiraling curves is simple and convenient, and, on this account, is preferable to most of the older and more complicated methods. Its use will simplify field operations without the necessity of resorting to tedious calculations or elaborate tables. Mr. Lea.

The tables of cost are comprehensive, and of much interest in affording a basis of comparison for current prices for the classes of work tabulated. These tables constitute a valuable feature of the paper, and the author is to be commended for furnishing this information, especially in view of the general dearth of data of this class in engineering literature.

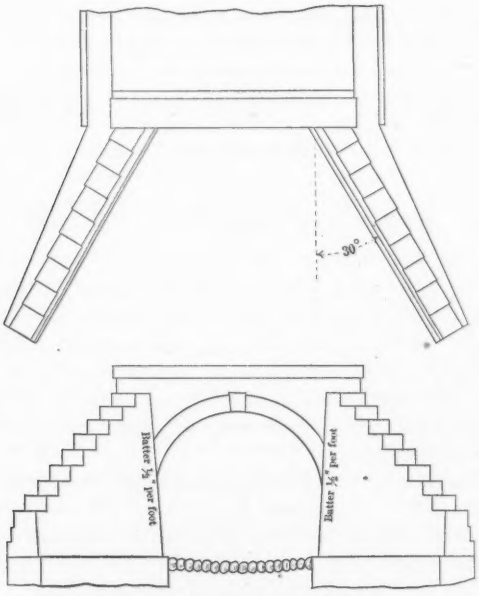
Judging from the photographs, the masonry, both in the arch and box culverts, was good; and the general design of the box culverts is in accordance with good practice. The writer thinks the use of bond or anchor stones in the box culvert paving would have been preferable. Such stones are several inches deeper than the regular paving stones and extend entirely across the floor of the culvert. Ordinarily, they are placed at intervals of from 6 to 10 ft., in the length of the culvert, and serve to hold the pavement in place in case of its undermining or washing.

*This discussion (of the paper by A. G. Allen, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for August, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to November 27th, 1903, will be published subsequently.

Mr. Lea. In the writer's opinion, the arch culvert designs are defective in two important features, namely:

1.—The wing walls at the up-stream end of the culvert have their axes parallel with the axis of the culvert.

2.—A shoulder or offset is left, at the junction of each wing wall with the trunk of the culvert, between the face of the wing wall and the face of the side wall of the culvert. Both of these objectionable features are eliminated in Fig. 10, which illustrates an arch culvert built under the writer's supervision.



DESIGN FOR AN ARCH CULVERT.

FIG. 10.

In arch culvert construction the writer's practice has been to build the upper wing walls splayed at an angle of about 30° to the axis of the culvert, and with their faces on line with the faces of the side walls of the culvert, at the junction of the wing walls with the trunk. This construction requires that the faces of the culvert walls shall be battered to correspond with the batter of the wing walls. In this design there are no shoulders or re-entrant angles at the upper end of the culvert below the springing line of the arch. The water is afforded a free and unobstructed entrance to the culvert, and there are no projecting surfaces to catch floating drift and débris.

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AN EXPERIMENTAL STUDY OF THE RESISTANCES TO THE FLOW OF WATER IN PIPES.

Discussion.*

By Messrs. E. G. Coker and George W. Fenkell.

Mr. Coker.

E. G. Coker,† Esq (by letter).—The authors, in commencing their investigations, do not appear to have given much attention to the important researches of Osborne Reynolds on the flow of water in pipes, now twenty years old. He first showed that water flowing in a pipe may be direct or sinuous, depending upon the relations between the velocity of the water, the temperature, and the diameter of the pipe; and he gave a formula, for the critical value of direct or stream-line motion, expressed in the form,

$$v_c = k\, D^{-1} f(T),$$

where v_c is the critical velocity, D is the diameter of the pipe, and $f(T)$ is $(1 + \alpha\, T + \beta\, T^2)^{-1}$.

He showed, further, that, for stream-line motion, the loss of head is proportional to the first power of the velocity and is influenced greatly by temperature; while, for eddy motion, the resistance is proportional to a higher power of the velocity and is less dependent on the temperature. These results were arrived at by a train of reasoning which appeals to the principle of the equality of dimensions of physical quantities, and the deductions were amply verified by his own experiments and others. It is somewhat surprising, therefore,

* Continued from September, 1903, *Proceedings*. See May, 1903, *Proceedings* for paper on this subject by Augustus W. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E.

† Assistant Professor of Civil Engineering, McGill University.

Mr. Coker. to see some of these conclusions stated as if they were newly discovered and therefore novel, whereas they have long since been accepted and find a place in modern textbooks.

Again, the authors express astonishment in finding that the values of n, in the formula, $H = m\ V^n$, is remarkably constant for pipes of the same material and smoothness, but this need hardly be a matter of surprise when it is remembered that, even for pipes of widely different materials and of different degrees of roughness, the value of n, in the great majority of cases, lies between 1.7 and 1.95, and there are many published experiments giving logarithmic plots for pipes of the same material and degree of roughness with lines practically parallel.

Most of the experiments recorded in the paper have been made for eddy motion in which a small difference of temperature between the water in the pipes and the laboratory does not cause serious error, but this is not the case when there is stream-line motion, and it is then very necessary to guard against a change of temperature in the flowing water by lagging or otherwise protecting the pipes. The temperature of the room where the experiments were carried out is stated to have been practically constant, but, apparently, there is no reference to the pipes being protected from change of temperature, and it would be interesting to know whether this precaution was attended to.

The method of reducing the results to a standard temperature appears to be open to criticism in that the corrections are based entirely on the results, and hence any errors in the experiments reappear in the correction factors. If this objection be removed it would be interesting to learn why the authors finally assumed a uniform correction of 4% per 10°, when, as appears from Fig. 3†, the correction should vary from 2.9 to 4.6 per cent.

If it is assumed that the total resistance, h, depends on powers of the pipe diameter, the viscosity, the density, ρ, and the velocity of the water, there is no difficulty in determining a correction factor for variations of temperature, t, in the form

$$\frac{d\,h}{h} = (n-2)\,\frac{\alpha + 2\,\beta\,t}{1 + \alpha\,t + \beta\,t^2}\,d\,t + (1-n)\,\frac{\rho}{1-\rho\,t}\,d\,t,$$

where the second term, involving the density, ρ, is, in general, negligible. This correction factor is independent of the experiments, except as regards n, which latter can always be determined with considerable accuracy, while the constants, α and β, relate to the known variation in the viscosity.

Mr. Fenkell. GEORGE H. FENKELL, Assoc. M. Am. Soc. C. E. (by letter).—As the title of this paper does not seem to limit the discussion to experiments upon the smaller sizes of pipes, such as those used by the authors, the writer will give the result of a few experiments which he made re-

† *Proceedings*, Am. Soc. C. E., for May, 1903, p. 456.

cently on the loss of head in 8 215 ft. of 60-in. cast-iron intake pipe at Erie, Pa. Mr. Fenkell.

In 1895 and 1896 the Commissioners of Water-Works of Erie, Pa., laid a cast-iron intake pipe from the pumping station on the south shore of Erie Harbor to within ½ mile of the north shore of the harbor. The top of this pipe was laid about 3 ft. below the natural bottom of the harbor, and the outer end provided with a submerged intake crib. As the manner of laying this pipe has been described*, it is sufficient to say that the pipe was coated with tar, and that sections 72 ft. 10 ins. long were made up on shore, launched, towed into position, sunk, and connected by divers, and that when the line was completed it was tested thoroughly for leaks. A profile of the line, made after the work was completed, shows that there is very little variation in the vertical alignment, except where the pipe approaches the surface, near the shore end.

The water passes through the gratings in the top of the crib, then through 6 ft. of 60-in. vertical pipe to a 60 x 60-in. tee, where it is deflected horizontally into the main line, whence it is conducted to the pumping station. The observations for loss of head were made in a 24-in. manhole in the water-works park near the pumping station, and between the crib and this manhole the only special is a 60-in., 35° curve. The top of the 6-ft. vertical pipe at the crib is provided with a 5-in. flange, and is about 18 ins. above the crib floor. By feeling through the ice with a piece of gas pipe, during the winter of 1892–93, the top of the crib seemed to be free from sticks and leaves, and no mud was found, either in the bottom of the crib or in the inside bottom of the 60 x 60-in. tee. No deposit could be felt at the 24-in. manhole, and the 24-in. riser at the manhole, which was set when the pipe was laid, seemed to be free from rust, although in places it was somewhat rough.

Erie Harbor is about 5 miles long by nearly 2 miles wide, and its greatest depth is about 29 ft. The water at the crib is about 23 ft. deep. As the passage from the harbor into Lake Erie is only about 400 ft. wide, storms never cause the water in the harbor to become very turbid.

The experiments were made on September 1st, 1903. The minimum temperature of the air during the previous night was 62° Fahr., and the mean temperature of the air when the observations were made was 68° Fahr. The temperature of the water was 66° Fahr.

The day was clear and the water unusually calm, there being but a slight breeze from the northwest. The mean velocity of the wind, as recorded by the United States Weather Bureau at the top of the Government building in Erie, was 6 miles per hour, but was probably considerably less than this on the harbor.

* *Engineering News*, Dec. 5th, 1895.

TABLE No. 12.—Loss of Head in 8 215 Feet of 60-Inch Cast-Iron Intake Pipe, at Erie, Pa.

September 1st, 1903.

This Intake Pipe was laid in 1895 and 1896.

Time.	Gallons per Minute.						Velocity, in feet per second, from Column 7	Loss of head, in feet.	Loss of head (Column 9) less 1½ times the velocity head.	Loss of head per 1 000 ft., in feet, from Column 10.	Value of c in Chezy formula.	Remarks.
	Gaskill pump.		Worthington pump		Total pumped.							
	Less 2½% slip.	Less 5% slip.	See note.	Less 5% slip.	See note.	Less 5% slip.						
(1)	(2)*	(3)*	(4)*	(5)*	(6)*	(7)*	(8)	(9)	(10)	(11)	(12)	(13)
9:00 A. M.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Closed down pumps.
9:50–10:34	.....	.....	.....	.....	0	0	0	0	0	0	.....	
10.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Started Gaskill pump.
10:50–11:20	1 613.7	1 568.2	.....	.....	1 613.7	1 568.2	0.178	0.02167	0.0.092	0.002547	99.8	
11:22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Increased speed.
11:25–11:50	2 569.8	2 497.3	.....	.....	2 569.8	2 497.3	0.283	0.04458	0.04272	0.005200	111.0	
11:52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	" "
12:00–12:20	3 467.1	3 369.2	.....	.....	3 467.1	3 369.3	0.382	0.09450	0.09111	0.011091	102.6	
12:30 P. M.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Started Worthington pump.
1:00–1:10	2 620.8	2 546.8	4 039.6	3 905.9	6 650.4	6 452.7	0.732	0.3976	0.38512	0.046880	95.7	
1:11–1:25	2 475.2	2 405.3	4 489.6	4 351.8	6 964.8	6 757.1	0.767	0.4340	0.42029	0.051163	95.9	
1:27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Increased speed.
1:30–1:50	2 511.6	2 440.1	5 736.0	5 618.1	8 307.6	8 058.2	0.914	0.5507	0.53125	0.064668	101.7	
1:53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	" "
2:00–2:10	3 367.0	3 271.9	6 513.6	6 313.7	9 880.6	9 585.6	1.088	0.7736	0.74603	0.090813	102.1	
2:11–2:20	3 458.0	3 360.3	6 513.6	6 313.7	9 971.6	9 674.0	1.098	0.8108	0.78272	0.095279	100.7	

* Column 6 is the sum of Columns 2 and 4. Column 7 is the sum of Columns 3 and 5. Column 7 is used for computing Columns 8, 10 and 12, Columns 2 and 4 are obtained by multiplying the revolutions by 182 and 552 galls., respectively, as these figures are used at the Erie Water-Works in computing the pumpage. In ordinary practice the length of stroke of the Worthington pump is sometimes increased ½ in.

Mr. Fenkell.

Mr. Fenkell.

The velocity of flow was determined by plunger displacement of the pumps. The Gaskill is a horizontal, compound, fly-wheel pumping engine, erected in 1886, with water cylinders 19½ x 36 ins., and rated at 5 000 000 galls. per 24 hours. The Worthington is a horizontal, compound pumping engine, erected in 1893, with water cylinders 29 x 49¼ ins. (49¼ ins. being the length of the stroke when observations were taken), and rated at 12 000 000 galls. per 24 hours. The Gaskill pump worked against a pressure of 98 lbs., and the Worthington pump against a pressure of 118 lbs., per square inch.

Hook-gauge readings were taken at intervals of one minute in the 24-in. manhole and also in the harbor, about 200 ft. east of this manhole, and Table No. 12 gives the results obtained. One and one-half times the velocity head is deducted from the total loss of head (see Column 10) to allow for loss at entrance and head necessary to produce the velocity, and 5% is allowed for the slip of the pumps (see note at bottom of table). The pumps were overhauled recently, and were in good condition.

The hook-gauge readings taken in the harbor showed the extreme variation of the elevation of the surface of the water to have been ¾ in.

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THEORY OF CENTRIFUGAL PUMPS AND FANS: ANALYSIS OF THEIR ACTION, WITH SUGGESTIONS FOR DESIGNS.

Discussion.*

By Messrs. Allen Hazen, Joseph Mayer and Theodore Horton.

Mr. Hazen.

Allen Hazen, M. Am. Soc. C. E.—The speaker has examined this paper with a great deal of interest, and feels that it is a very valuable addition to the literature on the subject. He has not attempted to follow the mathematical discussion.

During the past year or two he has had occasion to see quite a number of centrifugal pumps, designed and built in different shops, which departed radically from the old forms, and which were, in his judgment, better classed as turbine pumps or impulse pumps than as centrifugal pumps; and he has been much impressed with the fact that, apparently, the art of constructing these pumps has developed in certain shops to a point considerably in advance of that reflected by the literature of the subject.

Many of the matters which have already impressed him in connection with these pumps are discussed in this paper and are embodied in the designs submitted, although the designs recommended by the author differ widely in form from any pump which the speaker has seen.

The speaker believes that pumps of these advanced types, that is to say, pumps depending largely upon impulse action, and in which

*Continued from September, 1903, *Proceedings*. See *Proceedings* for May, 1903, for paper on this subject by Elmo G. Harris, M. Am. Soc. C. E.

the friction of water moving at high velocities over the pump surfaces is systematically reduced to the lowest possible point, will play a very large part in the pumping of the future. Mr. Hazen.

Among other things, the adaptability of such pumps to direct connection with high-speed rotary motors, their low cost and good efficiency will lead to their use in many places; and it is now well demonstrated that with properly designed pumps the old limit of economical lift of a centrifugal pump is no longer a real limit; it applied only to pumps of certain design, and when the design is adapted to the new service, it is possible to lift water to any required height with substantially the same efficiency that is obtained with very moderate lifts.

JOSEPH MAYER, M. Am. Soc. C. E. (by letter).—This paper is very valuable in some of its suggestions for improvements, but it is marred by incorrect theories as to the vanes and the factors governing the discharge. There is also an erroneous equation (*XV*) on page 508.* If the instructions given in the paper for the derivation of this equation are followed, there is obtained $w^2 = g\ (h - k)$, and not $w^2 = g\ (h + k - 2p)$, as given by the author. Mr. Mayer.

This error explains the contradiction between the author's Equations *XIV* and *XV*.

As regards the discharge, Q, the author seems to miss entirely some of the essential conditions governing it. The pump produces a total head, H, which is given correctly by the author. This total head is used to overcome the difference in level between the lower and the upper basins and all the resistances opposing the flow from one basin to the other, through the suction pipe, the pump and the force pipe. The loss of head in the pipes varies approximately as the square of the velocity of flow through them. The loss of head in the pump is composed of that by friction in the channels between the runner- and guide- vanes and that due to the only partial transformation into pressure of the absolute exit velocity from the runner. The first part is different for open and for enclosed runners, since it is governed in the former case partly by the absolute velocity of the water flowing along the stationary casing, and in the latter altogether by its velocity relative to the runner, which latter may be only a fraction of the former.

A runner which is in contact with water remaining in the pump causes, by the friction between it and this water, an increase in the power required to drive the pump with a given velocity, but this does not cause any loss of head in the water flowing through the pump.

If the constant peripheral velocity of the runner is u, then the total head, H, of the pump given by the author is

$$H = \frac{u^2 + u\,V \cos.\,\beta}{g}$$

* *Proceedings*, Am. Soc. C. E., for May, 1903.

Mr. Mayer. If the difference in level or head between the upper and lower basins, or the lift, is H^1, then $H - H^1$ is the head available for overcoming all the resistances to the flow of the water through the pipes and the pump. All these resistances are functions of the velocity of flow; the velocity of flow, and the consequent discharge, is therefore a function of $H - H^1$; it is not proportional to u, as stated by the author, but is 0 for all values of u, as long as $H^1 = H$.

The author uses the term "efficiency of pump" in a loose manner, implying that the efficiency is the ratio $\frac{H^1}{H}$. The efficiency of a centrifugal pump, as of any other machine, is the useful work done by it divided by the work put into it by the motor. The useful work done by the pump is the weight of water discharged multiplied by the lift, say $H^1 w$.

The work put into the pump is $H w$ plus the work done to overcome the friction in the bearings and that between the runner and the water remaining in the pump, plus the work done in driving the leakage past the pump. If the sum of the last three items is A, then the efficiency of the pump is

$$\frac{H^1 w}{H w + A} = \frac{H^1}{H + \frac{A}{w}}$$

This, evidently, is always smaller than $\frac{H^1}{H}$, since A can never be 0.

The author is in error as regards the principles which must govern the design of the vanes. He asserts that in Fig. 20 the velocity of exit at d will be much larger than at a. The opposite is true. He neglects the fact that on account of the circular motion of the water beginning on the vertical line, $f b$, and the consequent increase of pressure from b toward f, due to centrifugal force, the relative velocities in the section, $b f$, must decrease in going from b to f, since the increase in pressure can only be produced at the expense of a decrease in velocity. The average velocity in $b f$, therefore, is less than the velocity, u, of the vane. Since the water originally above the level of f will nearly all pass up the vane, there will be a rise at b; that is, the vertical distance from f to the surface will be larger than $b f$ in the figure. During the relatively circular motion along the vane the velocity of each particle of the water (neglecting the effects of gravity and friction) will be constant, but those particles near the vane will move more slowly than those at the surface; the velocity of the particles gradually decreases and the pressure gradually increases as one passes from the surface to the vane. Before and near $a d$, of the figure, the same condition prevails, the total head, velocity plus pressure head, being the same from the surface to near the vane. Shortly beyond $a d$, where the motion is straight, the pressure is uniform

through the whole cross-section, and also the velocity. The friction along the vane was here neglected; this will cause a diminution of the velocity of the particles passing at *d*. Mr. Mayer.

The vanes of an axial-flow pump will now be considered. In such a pump each particle of water maintains during its flow through the vanes an approximately uniform distance from the axis of the pump, while, in a radial-flow pump, this distance increases. This difference in the direction of flow, relatively to the runner, entails a fundamental difference in the proper shape of the vanes.

It is generally conceded that the vanes should be shaped so that the water enters without shock, and it is perceived that the tangent of the angle, Δ, of the author, between the directions of the relative entrance velocity and the velocity of the runner at the entrance should be equal to $\frac{v_1}{u_1}$, where v_1 is the absolute velocity of entrance of the water into the runner and u_1 is the tangential velocity of the runner at the point of entrance (see Fig. 38). The elevation shows the intersections of the vanes with a cylinder, of radius, r, after development; r being the mean radial distance of the vanes from the axis of the runner. If the radial width of the vanes near the entrance is constant, and if the velocity of entrance of the water is to be constant, the first part, *a b*, of the vanes should be straight. If this part is not straight, but convex toward the flow, then the velocity of entrance, as the vane passes a given point, increases, while the part *a b* is passing in front of that point, in proportion to the increase of the tangent of the angle of inclination of the tangent to the vane curve with the plane of rotation. This increased velocity is suddenly checked when the point of the next vane comes around. If the vane recedes far from the straight line, *a b*, the acceleration needed—which must extend for some distance into the suction pipe—may not be produced, and a vacuum will be created on the farther part of the back of the vane. There will certainly be a vacuum at the front of the vane, at and near the entrance. The velocity of entrance will be rapidly oscillating.

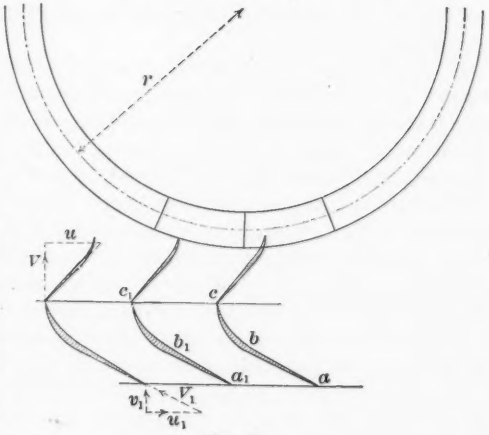


FIG. 38.

Mr. Mayer.

To secure absolute uniformity of the entrance velocity, the vane should be straight to the point where it begins to be covered by the following vane looking in the direction of the absolute velocity of the entering water. A small variation in the entrance velocity, however, causes little loss of head; it is, therefore, sufficient to make the vanes straight for a shorter distance, say up to the point where they are covered by the following vanes when looking at right angles to the relative entrance velocity.

The lengths of the channels in the runner, and the loss by friction in it, are thereby reduced. This argument must be modified when the vanes are of decreasing radial width near the entrance. Then a uniform absolute velocity at the entrance produces an increasing absolute velocity as the vane is entered. The curve of the vane, in this case, should begin at the entrance. If the rate of reduction of radial width of vanes is given, their proper curve corresponding to a uniform velocity of entrance can easily be constructed. The acceleration of the water, in this case, does not extend beyond the vanes, the corresponding reduction of pressure, therefore, is small, and can be calculated accurately.

If the remainder of each vane is an arc of a circle of radius, ρ, the water will begin to be deflected from its straight course at $b\ b_1$, it will, after this, move relative to the wheel approximately in arcs of circles of radius, ρ. Near the line $c\ c_1$, and within the wheel, the mean relative velocity of the water is V. The centrifugal force produces an increase of pressure as one advances from c to c_1. Since the pressure in front of the vane at c_1 is greater than the pressure in the rear of the vane at c, the velocity at c_1 in front must be less than at c in the rear of the vane. Near the center of $c\ c_1$ will be the mean velocity, V, and the mean pressure, p. The absolute pressure in the rear of the vane at c cannot be less than 0. The centrifugal force along $c\ c_1$ produces a difference of pressure, p^1, per unit of area at the two points, c and c_1, where

$$p^1 = \frac{d}{g}\frac{W}{\rho}\frac{V^2}{}$$

where

$d = c\ c_1$;
$W =$ weight of cubic unit of water;
$g =$ acceleration of gravity;
$\rho =$ radius of curvature;

all in the same unit.

The foregoing equation is only approximate, but sufficiently so, if the variation in velocity between c and c^1 is not very large.

One-half this pressure, p^1, will be the reduction of pressure at the back of the vane at c, below the mean pressure, p. $\frac{p^1}{2}$, therefore, must be smaller than p plus atmospheric pressure; otherwise a vacuum

will be produced at c, in the rear of the vane. This gives certain limits for V and ρ and d which must be kept in view in determining these quantities. Mr. Mayer.

The author seems to appreciate, in Figs. 23 and 24, the necessity of having the part of the vanes near the entrance straight, but he neglects this condition in all other vanes shown. He shows in Fig. 24 fixed guide vanes with a straight entrance. The conditions determining the shape of these vanes, however, are different from those in the runner. Either the pressure is much greater than at the entrance to the runner, or the angle between the entrance and exit of these vanes is much less than in the runner. The velocity decreases during the flow through these vanes, and the pressure increases. Consequently, there is much less chance for the formation of a vacuum. The curvature of these vanes may be much sharper, and may begin nearer the entrance, it can be calculated in a similar manner to that of the vanes of the runner. The vanes shown on Fig. 24, evidently, would better perform the office of turning all the outflowing water into one direction, if their straight part were shorter and their curved part were of greater radius.

The use of such fixed guide-vanes, however, can be avoided, with advantage, by introducing, at the exit from the runner, a circular channel gradually increasing in cross-section, such as shown by the author for radial-flow pumps.

Vanes of Radial-Flow Pumps.—The condition that the water should enter the pump with uniform velocity, and, therefore, without shock from the moving vanes, determines the curve of each vane as far as it is not covered by the following one when looking from the center of the pump. This curve is a spiral when the axial width of the vanes near the entrance decreases in proportion to the distance from the axis. If the axial width of the vanes decreases at a greater or smaller rate than the distance from the axis increases, then the radial velocity of the water must increase or decrease as its distance from the center increases, if a uniform velocity of entrance into the wheel is to be secured. If the rate of decrease of axial width of vanes is given by an axial section of the pump, then the proper shape of the vanes near the entrance, so as to secure a uniform entrance velocity, can easily be constructed. The part of each vane covered by the following one can be an arc of a circle meeting the circumference of the wheel at a right angle. It is not essential that the entrance velocity should be absolutely uniform. The circular part of the vanes, therefore, can begin somewhat earlier than given above, without much loss at the entrance, and with a reduction of the friction loss in the wheel. See Fig. 39. If the circular arc for the latter part of the vane is drawn tangent to the assumed end of the first part of the vane with arbitrary radius, and if the periphery of the wheel is drawn normal to this circle, then the

Mr. Mayer.

absolute curve of the moving water near the exit from the runner can be constructed, provided the velocity of the runner, the radial width of the vanes, and the discharge are given. From this curve of the absolute motion of the water, in the runner near its exit, its radius of curvature at the exit can be determined. This corresponds to the radius, ρ, of the axial-flow pump.

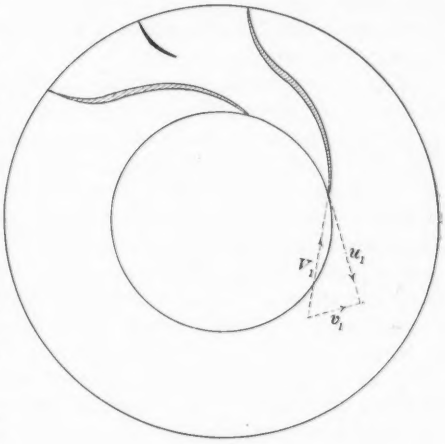


FIG. 39.

The centrifugal force between two succeeding vanes can then be calculated in a similar manner to that shown previously. Half the pressure from centrifugal force subtracted from the mean absolute pressure at the exit from the pump, calculated from the formulas, gives the absolute pressure at the back of the vanes at their outside ends. This should be more than 0. If this is not the case, then the number of vanes near the periphery of the pump should be increased, or their radius of curvature made larger. The number of vanes can often with advantage be made twice as large near the periphery as near the center. The shape here suggested for the outside part of the vanes is to some extent arbitrary. To reduce the loss of head by friction during the flow through the vanes, their radial depth should be as small as is compatible with the avoidance of a vacuum and of considerable shocks at the entrance. The best vane, therefore, will be obtained if the curvature is made as sharp as is compatible with these conditions. If this is done, the absolute pressure on the back of the vane, from the periphery to the point where the vane is not covered by the following one, will be 0. From this condition, the best curve of the vane can be constructed when the amount of flow, the axial widths of the vane, and the velocity of the wheel are given. The process, however, is complicated.

When the pressure, p, is great, and the velocity, V, is small, ρ becomes very small. In this case no vacuum need be feared, and the curvature of the latter part of the vanes can be chosen freely to suit other considerations.

If the vanes are designed correctly, which is rarely done, a pump can be constructed which will work economically with much greater speed and entrance velocity than is practicable with a badly designed pump.

Mr. Mayer.

Most of the designs of the author have very complicated vanes of double curvature, which can hardly be calculated and would be difficult to mould exactly to the calculated shape.

The surface of the vanes of radial-flow pumps is cylindrical, that of the vanes of axial-flow pumps is a skew surface produced by the motion of a straight line always intersecting the axis and the vane curve on the cylinder with radius, r (given previously), and always remaining perpendicular to the axis.

The Radial Depth of Vanes of Axial-Flow Pumps.—To make clear one of the most important conditions which must govern the radial depth at the exit from such vanes in an economical pump, the author's compound pump of Fig. 32 will be considered.

The radial depth of the vanes scales 2 ins.; the head, H, produced by one set of moving vanes, varies, then, from $\frac{u_o^2}{g}$ to $\frac{u_1^2}{g}$, if u_o and u_1 are the least and greatest velocities. d_o is 12 ins.; d_1 is 16 ins., with 500 revolutions per minute;

$$u_o = 26.18 \text{ ft.};$$
$$u_1 = 34.91 \text{ ft.};$$
$$\frac{u_o^2}{g} = 21.28 \text{ ft};$$
$$\frac{u_1^2}{g} = 37.85 \text{ ft.}$$

The head corresponding to the mean diameter of 14 ins. is

$$\frac{30.54^2}{32.2} = 29 \text{ ft.}$$

The heads produced by the two sets of vanes are twice those given above, or from 42.56 to 75.70 ft. If the adverse head, outside of the pump, equal to the lift plus the losses of head in the suction and force pipes is 50 ft., then, evidently, the water will flow backward at the inside of the vanes with a velocity that will create losses of head equal to 7.44 ft. The velocity will be small, as there will be much loss by shock where the water enters new sets of vanes. The water will flow forward at the outside of the vanes with a velocity that will create losses of head equal to 25.7 ft. The loss of head suffered by the water in flowing through the pump near the outside of the vanes will be 25.7 ft. On account of the extremely variable velocity of flow in the channels between the vanes, there will be much internal friction of the water by eddies. The direction of the vanes cannot be adapted to these various velocities, consequently there will be much shock at the entrances to the different sets of vanes. A large ratio of $\frac{d_1}{d_o}$, therefore, is very objectionable in a pump with axial outflow from the vanes; the result, inevitably, must be a low efficiency. All calculation of the lift, or amount of flow corresponding to a given velocity, u, in a pump like that here considered, must be futile; any attempt to design for it vanes that will avoid shock is equally hopeless.

Mr. Mayer. *The Efficiency of Centrifugal Pumps.*—The writer will disregard the author's warning, at the risk of endangering the reputation of mathematics, trusting that she is strong enough to defend her reputation, and will attempt to ascertain by calculation, as far as possible, the conditions which must be complied with to secure an efficient centrifugal pump.

The efficiency of a machine is its useful work divided by its total work. The total work is the useful work plus the wasted work or the losses.

In a rotary pump the useful work is the product of the lift into the weight of water discharged. The losses are:

First.—The friction in the bearings;

Second.—The friction between the runner and the water remaining in the pump;

Third.—The waste by leakage from the pressure to the suction side of the runner;

Fourth.—The friction of the water while flowing through the channels between the vanes;

Fifth.—The loss in the transformation into pressure of the velocity given to the water by the vanes of the runner;

Sixth.—The losses in the suction and force pipes, if these are considered a part of the pump.

The first loss is very small, especially if the pump is well balanced and driven by an electric motor. Its size depends on the efficiency of lubrication and the condition and design of the bearings.

The second loss can be avoided almost wholly by surrounding the pump with air instead of water, as suggested by the author.

The third loss can be kept low by proper design and accurate workmanship.

The first three losses affect the efficiency, but not the lift, of the pump. The third loss reduces the amount of discharge.

The laws governing the losses of head in the suction and force pipes are well known, as the velocities in them are not unusual. These losses can be calculated accurately for any given discharge.

The laws governing the losses during the flow through the vanes are not accurately known, as the velocities are generally larger than the range of the experiments, and as the channels are somewhat irregular; but the known formulas for the relation between velocity, friction, and hydraulic radius will give approximately true results. These will be a much better guide than absolute ignorance. The writer, therefore, will use Kutter's formula:

$$V = c\sqrt{RS} \qquad \ldots\ldots 1$$

where

$$c = \frac{41.6 + \dfrac{0.00281}{\text{Slope.}} + \dfrac{1.811}{n}}{1 + \dfrac{\left(41.6 + \dfrac{0.00281}{\text{Slope.}}\right) n}{\sqrt{R}\ (\text{in feet})}};$$

in which n is the coefficient of roughness, and may be taken = 0.009. It may be somewhat more in a new pump with rough channels, but will soon decrease with the use of the pump. Mr. Mayer.

The slope in this case is large.

The formula for c, therefore, becomes approximately

$$c = \frac{243}{1 + \frac{0.374}{\sqrt{R\ (\text{in feet})}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots II$$

From Equation I we obtain

$$S = \frac{V^2}{c^2 R}$$

The loss of head, h^1, in a length, l, of a conduit is

$$h^1 = S\,l = \frac{V^2\,l}{c^2\,R}$$

If $\beta = 90°$, then

$$H = \frac{u^2}{g},$$

and

$$\frac{h^1}{H} = \frac{g}{c^2}\frac{V^2}{u^2}\frac{l}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots III$$

In this formula, V is the velocity of flow through any channel, either in runner- or guide- vanes, relative to the channel walls. $\frac{h^1}{H}$ is the fraction of the total head lost in the channel considered.

If V and R vary much in different parts of a channel the channel should be subdivided into different parts with nearly constant V and R in each part, and the losses of head of succeeding parts should be added.

If the relative velocity against the different walls of a channel is different, as in open runners, then the losses of head by friction against the walls with different velocity must be calculated separately and added. This can easily be done if it is considered that the friction against a part of the periphery of a channel is equal to the friction with the same velocity against the whole periphery, multiplied by the ratio between the length of the part and the length of the whole periphery.

By means of Equation III, the fraction, $\frac{h^1}{H}$, for the whole length of the channels between the vanes can be calculated for any proposed shape of the vanes.

Equation II shows that c increases slowly with the increase of R. l is the length of the channel through the vanes, and it increases with R. On account of the increase of c with R, pumps of large discharge in comparison with the lift lose a smaller fraction of the total head, by friction during the flow through the runner- and guide- vanes, than

Mr. Mayer. pumps of small discharge compared with the lift. The formula shows that l should be as small as it can be made. This can be accomplished by making the curvature of the vanes as sharp as is compatible with the conditions previously mentioned. The shape of the channels should be such as to give a large R; that is, they should be as nearly square as other conditions allow.

If the head is large, several pumps in succession, or a compound pump, will lose less in efficiency by the friction in the channels between the vanes than a single pump of the total lift, as R will be larger in the former case.

The formulas given by the author and in the foregoing leave a wide range of choice for the velocity of flow through the pump. Trial designs of vanes should be made for different values of this velocity, and the consequent relative loss by friction in the channels through the vanes should be calculated by means of Equation III. By repeated trials, a form of vane will be found which will give nearly the smallest possible loss of head by friction in the channels between the vanes. The conditions previously given, to avoid a vacuum and a rapidly oscillating entrance velocity, should always be observed.

The loss by the only partial transformation into pressure of the absolute exit velocity from the runner may be estimated, preliminarily, at 10% of H, for a well-designed pump without sudden enlargement of the exit channels. This loss is increased by any increase in the assumed relative exit velocity, V, from the runner. This latter, therefore, should be taken somewhat smaller than would be prescribed by the smallest friction loss between the vanes.

The calculation of the pump must start with the known desired lift H^1 and discharge Q. The losses of head in the adopted suction and force pipes can then be calculated and added to H^1. This sum should be increased by from 20 to 33%, to obtain the theoretical head, H. The former percentage of addition should be used for pumps of large discharge, the latter for pumps of small discharge, as compared with the head. u can then be calculated, and the vanes designed for different velocities of flow through the pump. The quantity of flow through the channels between the vanes of the runner must be assumed equal to Q plus the estimated leakage past the runner.

The loss of head by friction in the channels between the different trial vanes must then be calculated and the best ones adopted. If the first guess for the losses of head in the pump was far out of the way, a new and better guess can be made and better vanes designed.

The remainder of the six losses above mentioned should then be calculated, and, where calculation fails, guessed at. This determines the efficiency of the pump and the power of the motor required. After the pump is built it should be tested. From the tests the un-

known factors previously guessed at can be inferred more closely, and in future predicted more accurately. The loss about which least can be inferred from general hydraulic principles is that due to the only partial transformation of the exit velocity from the runner into head. The laws governing its size must be inferred from numerous tests with pumps actually built. Mr. Mayer.

Loss of Work by Friction between the Runner and the Standing Water Surrounding It.—We have $V = c\sqrt{R\,S}$, for the relation between velocity and friction in a water pipe. From this, $S = \frac{V^2}{c^2 R}$, and from this is obtained the work needed to overcome the friction on a length, l, of the pipe

$$S\,l\,a\,V\,W = \frac{W}{V^2}\,\frac{a}{R}\,l\,V^3,$$

where a is the area of cross-section of the pipe; and $\frac{a}{R} = p$, the periphery of the pipe.

If we introduce p for $\frac{a}{R}$, and call the work of friction, F, we obtain

$$F = \frac{W}{c^2}\,p\,l\,V^3.$$

$p\,l$ is the area along which the friction occurs, and V^3 is the velocity of the passing water.

The standing water in the pump will gradually begin to revolve with the runner, and the relative velocity between the runner and the water will thereby decrease. If the case fits the runner closely, the velocity of the water will be half that of the runner. This will reduce the friction between the runner and the water to about one-eighth; but there will arise friction between the water and the case, which, for close fit between the runner and the case, is about equal to the friction between the runner and the water. The power to overcome the friction between the water and the case must also come from the runner. The total work of friction, therefore, is approximately one-quarter of that between quiet water and the runner.

Different parts of the runner have different velocities, and the formula for F must be changed accordingly. The two considerations mentioned suggest the formula

$$F = \Sigma\,\frac{W}{4\,c^2}\,p\,l\,V^3 = \frac{W}{4\,c^2}\,\Sigma\,p\,l\,V^3.$$

The case here considered, however, is widely different from that of the flow of water in a pipe or an open channel. The results obtained by the formula, therefore, may not correspond with the facts. Experiments with a pump arranged for running in either water or air, and driven by an electric motor of known characteristics, would be needed to determine the proper coefficients for the formula. Experiments

Mr. Mayer. with a metal disk and with a cylinder revolving in water would be still more suitable for ascertaining the general law of this friction.

The distance of the case from the runner has probably little influence on the amount of work lost by this friction. If the case is far distant from the runner, a large part of the total friction will be internal friction in the water, and the friction between the water and the case will be correspondingly smaller.

The formula is here given merely as a hypothesis of the probable law of this friction. It needs confirmation by experiment, because several steps in the argument are mere surmises.

It is hard to see what the author expects to accomplish by his proposed adjustable pump that could not be obtained in a cheaper, better, and simpler manner by a throttling valve in the force pipe. The narrowing of his exit channels from the runner will decrease the quantity of flow, as desired, but it will cause an increased loss of head in these channels. The vanes of the runner can be made quite suitable only to one ratio between velocity of flow and velocity, u. The best efficiency, therefore, cannot be maintained for different discharges accompanying the same speed of the pump.

The introduction of these additional vanes into a part of the pump with high velocity must inevitably decrease much the obtainable maximum efficiency. The introduction of a throttling valve into a force pipe with small velocity would have little effect on the maximum efficiency of the pump, and, if partly closed, it would reduce the maximum efficiency of the pump no more than the corresponding reduction of the smaller maximum efficiency of the author's adjustable pump. If the speed of the motor can be varied, a reduction of speed will bring about a reduction of discharge with less loss of efficiency than is inevitable with the contrivance suggested by the author.

The author is correct in assuming that the field of usefulness of rotary pumps will be largely increased by an improvement in their efficiency.

Rotary pumps of high efficiency, driven by steam turbines or electric motors, may be expected to encroach largely on the present field of reciprocating pumps, for which steam turbines and electric motors cannot be used with advantage.

To sum up the writer's review of the paper: His formulas for rotary pumps, with one unimportant exception, are correct, but, alone, they are utterly inadequate as a guide for the design of an economical pump. Such a guide can only be obtained from a careful mathematical analysis of the conditions governing the efficiency of rotary pumps. Most of the defects of the paper are due to the refusal of the author to undertake such an analysis. A perfect mathematical analysis of these conditions may be impossible, but it

is easy to go much further than the author did, and thereby to avoid the errors into which he has fallen. Only by carrying the mathematical investigation as far as possible can the results of tests on completed pumps be so interpreted as to ascertain the complete laws governing the efficiency of rotary pumps, and only in this way can a complete guide to the correct design of rotary pumps be finally obtained. Mr. Mayer.

The author's theory of the vanes, as far as it goes, is incorrect, and it does not go nearly far enough. His vanes, like those of most pumps, are largely guesswork. He neglects in his investigation some of the governing factors determining the discharge. His statements in regard to it are therefore in error. He neglects the inequality of head produced at the inside and outside of the discharge ring of axial-flow pumps, and, in consequence, recommends an evidently inefficient design. He suggests an adjustable pump of no value. He makes a distinction between centrifugal and impulse pumps, saying that they are based on different principles. His equations do not sustain this assertion. The essential principle of both is the same. The water is given a velocity by means of vanes pushing it along. This velocity is reduced and transformed into pressure. The proper shape of the vanes is different for radial and for axial motion of the water. This is the only essential difference between centrifugal and impulse pumps. Centrifugal force always arises when a body is forced to move in a curve. There is no good reason given why the pressure during the flow through the runner should be constant or variable in either kind of pump. The different values of this pressure may be chosen to suit other conditions. All unnecessary restrictions are harmful, because they limit the possibility of nearly satisfying all essential conditions of great efficiency.

The author also suggests compound pumps for high lifts, which, if they are properly designed, will give good results.

The merit of the paper lies mainly in a simple derivation of correct formulas, and in suggestions for methods of balancing and reducing the friction. In spite of all defects the paper is a valuable contribution to the theory of rotary pumps.

THEODORE HORTON, Assoc. M. Am. Soc. C. E. (by letter).—It is always a pleasure to find a subject, the mathematics of which might be termed burdensome, treated in a simple and practical manner, as the author has done with the subject of the centrifugal pump. The writer believes, however, with the author, that the forces acting within a centrifugal pump are so varied and intricate, and the assumptions upon which any theory must be based are in general so different from conditions in practice, that any deduction can hardly be considered other than a general guide to experimentation. Mr. Horton.

That this subject has been overlooked by previous writers upon

Mr. Horton. hydromechanics, however, as stated by the author, can hardly be reconciled by one who has read the masterly paper by William Cawthorne Unwin, M. Inst. C. E., entitled "The Centrifugal Pump." *

From a comparison between the two theories advanced by these authors, it appears that, beyond the preliminary principles of the Bernoulli theorem, there seems to be little in common ; but this, as intimated, is due principally to the difference in the preliminary assumptions. In Mr. Harris' analysis a radial prism of liquid upon the rotating wheel of unit area subject to purely centrifugal force is assumed, and an equation is deduced for the pressure at the outer radius of the wheel. Flow is next assumed to take place, and an equation is deduced for velocities of flow through the wheel, in terms of this pressure head. A final equation is deduced for the total head on the wheel, as follows :

$$H = \frac{v^2 + u \cos. \beta}{g}$$

This equation is surely a simple one, but the assumptions are surely very far from the real conditions of flow within the pump, and, as Mr. Venable has pointed out, the equation for flow corresponding to the pressure head is that corresponding to a free discharge against no external pressure.

In Unwin's analysis, on the contrary, no conditions are assumed regarding the action of the water within the wheel, other than what take place in actual practice. Instead of assuming a prism of water of uniform area and velocity, the column of water, as it actually moves through the wheel, with its changing sections and changing radial velocities, is considered, and, in terms of these variable elements, formulas are deduced for various portions of the wheel. Thus, for the case of a pump with a spiral casing, the following equation for the total head is given :

$$H = \frac{V_o^2 - V_i^2}{2g} - \frac{u_o^2 \operatorname{cosec.}^2 \phi \quad u_i^2 \operatorname{cosec.}^2 \Theta}{2g} + \frac{V_i u_i \cot. \Theta - u_i^2 \cot.^2 \Theta}{g}$$

$$+ \frac{1}{g}\left[v_s (V_o - u_o \cot. \phi) - v_s^2\right] - \frac{u_i^2}{2g}$$

In this equation:

H = Theoretical lift, as measured from the inlet of the pump to the discharge from the volute;

V_i = Velocity of rotation of the wheel at the inner radius;

V_o = Velocity of rotation of the wheel at the outer radius;

u_i = Radial velocity of water at the inner radius of the wheel;

$$= \frac{Q}{2 \pi r_i d_i - n d_i t \operatorname{cosec.} \Theta}$$

* *Minutes of Proceedings*, Inst. C. E., Vol. LIII., 1877-78.

Mr. Horton.

u_o = Radial velocity of the water at the outer radius of the wheel;

$$= \frac{Q}{2\,\pi\,r_o\,d_o - n\,d_o\,t\,\text{cosec.}\,\Theta}$$

Θ = Angle which wheel vanes make with inner circumference of wheel;

ϕ = Angle which wheel vanes make with outer circumference of wheel;

V_s = Velocity of water in volute chamber;

Q = Discharge of pump per second;

r_i = Radius of inner edge of wheel;

r_o = Radius of outer edge of wheel;

d_i = Depth of vanes at inner edge of wheel;

d_o = Depth of vanes at outer edge of wheel;

t = Thickness of vanes;

n = Number of vanes in pump disc.

This equation, at first glance, seems to be somewhat formidable, and it is reassuring, indeed, to note that in practice the third term on the right vanishes, and, unless the casing is badly designed, the fourth term may usually be neglected. In its simple form, however, the equation may be considered complete, and, in the opinion of the writer, it is a true expression for the forces which act within the pump. The concluding remarks of Mr. Unwin, though based as they were upon experience and experiments in the early stage of development of this class of pumps, lends even more confidence to the truth of his analysis, and are worthy of presentation here. He concluded as follows:

"There appears reason to expect considerable advantage from the use of a whirlpool chamber in centrifugal pumps; and it is extremely desirable that experiments should be made on pumps so constructed. If such experiments are undertaken, it is of primary importance to design the whirlpool chamber in such a way as to prevent irregular and eddying motion. If that cannot be done, guide-blades must be used. But guide-blades are not only an additional complication in the construction of the pump, but when fixed they are exactly adapted to only one discharge, and if movable, they require complicated arrangements for moving them.

"In Plate 13, sections have been shown of three types of pump of the varieties discussed in this paper. The German pump, with a spiral casing, nearly corresponds to the second type. The other two are pumps with whirlpool chambers. One of these is of a form originally designed, the author believes, by Professor James Thomson; and pumps of this kind were constructed under the author's superintence many years ago. The other pump is the pump on which M. Decœur experimented, as mentioned above. Neither of these corresponds exactly with what, in the author's opinion, is likely to prove the best form. Such a pump should, the author believes, fulfil the following conditions:

"(1) The inner angle of the vanes should correspond to the direction of the relative motion of the water with the normal discharge.

Mr. Horton.

"(2) The outer angle of the vanes should be moderately large, say from 30° to 45°. This would insure a more moderate speed of the pump, a smaller pump for a given discharge, and a more rapid increase of discharge with increase of speed.

"(3) A moderately large whirlpool chamber to utilize the energy of motion of the water discharged from the pump disc.

"(4) A suitably proportioned spiral discharge chamber.

"(5) The passage between the whirlpool and discharge chamber should be so accurately proportioned as to secure, as far as possible, a uniform flow all round from the whirlpool chamber into the discharge chamber. If this passage is of varying section, the regular motion in the whirlpool chamber would more or less be broken up.

"When the highest efficiency is not required, then a pump with a spiral chamber of the best proportions, as defined above, would be more compact, and should give fairly good results. In that case, probably Θ might be advantageously made somewhat smaller than the values given above; but an extremely small angle is probably disadvantageous.

"Whether these views as to the best type of pump are adopted or not, the author hopes that the formulæ for the speed and efficiency of pumps which have been obtained may be of use. It still remains to discuss the influence of friction on the efficiency and speed of the pump, and to this subject the author hopes at some future time to return. It only remains to express his sense of the great value of the experiments carried out by Mr. Parsons, the results of which have been so frequently quoted in this paper. Without the confirmation of theoretical results by the data thus furnished the author would hardly have ventured to publish this paper."

Turning now to the more practical consideration of the subject, the writer, not long ago, had an opportunity of making studies, regarding the action of centrifugal pumps, which may be of interest, as they involved some points relating to practical design. At that time he was connected with the Metropolitan Sewerage Commission, of Boston, Mass., and, under the direction of William M. Brown, M. Am. Soc. C. E., Chief Engineer of the Commission, was in charge of the official tests of the additional centrifugal pumping plants then being installed at the four pumping stations of the sewerage system.

The pumping engines at three of these stations were of the same make and capacity, but operating under different heads. Each was a triple-expansion horizontal engine driving a vertical shaft to which was directly connected the centrifugal pump. The pumps had a nominal capacity of 60 000 000 galls. per day, were relatively of large diameter and had ample water passages. As might be expected with pumps of this type, there was little trouble in attaining the required duty, which, as the writer remembers it, was about 80 000 000, a figure which compares favorably with duties obtained from pumps of the piston type. The fourth pumping engine, however, was of very

different design, operating under different conditions, and since this plant was unaccepted for a long period, during which many alterations were made, it will be described more in detail. Mr. Horton.

The contract called for a pump having a capacity of 13 000 000 galls., capable of developing 50 000 000 duty under a head of 13 ft., measured between water levels in the suction well and discharge sewer. The machine offered was a pump operating on the center of a horizontal shaft driven by a vertical, cross-compound, slide-valve engine, with cylinders at the two ends of the shaft. The pump, itself, in the writer's opinion, was well designed, the wheel, disc chamber and casing being worked out most carefully on theoretical lines, and compared with many successful wheels already built. The cylinders were of a good design for engines of this class, having an adjustable cut-off on the high-pressure cylinder. The clearance was too large for good economy, but this, it was claimed, was an inherent fault due to the type of valve motion. The pump was to be operated under a suction lift of some 8 or 9 ft., and the passages leading to and from the pump were somewhat contracted.

On its first trial, the pump failed to develop even approximately the required duty, although the capacity was nearly reached. This resulted in a long series of tests and changes, which were both interesting and instructive. The first step was to establish a curve of efficiency under a constant lift. This was obtained by running efficiency tests under different rates of discharge. The rates of discharge were obtained from gauge readings in the station which registered the depths in the discharge sewer, the latter having been rated previously by means of current meter measurements. This efficiency curve showed that the maximum efficiency, and consequently the maximum duty, was attained when the rate of discharge reached 10 000 000 galls., and then dropped off, at first gradually and afterward quite rapidly, so that, when the contract capacity of 13 000 000 galls. was reached, the efficiency and duty were quite low.

This indicated that the capacity of the pump was insufficient, or that the suction and discharge passages were too small. In the hope of increasing the capacity of the pump, extensions to the blades were made by bolting on small plates of the proper thickness and curvature. This resulted in no improvement, and they were finally taken off.

The next step was to place pressure and vacuum gauges at various points on the wheel, casing, volute, and suction and discharge passages, and tests were then run under various speeds, to determine where there might be excessive losses. These tests were very useful, and soon showed that there were no undue losses within the pump casing, but some excessive losses in the suction pipe. By substituting a trumpet-shaped entrance pipe, and enlarging its diameter at the same time, and by substituting a larger curve at a right-angle bend, these losses were reduced materially.

Mr. Horton.

Attention was then turned to the steam end. A calorimeter first showed that the steam contained but a fraction more than 1% of moisture, which was hardly considered serious. The cards from both cylinders were almost ideal, except during one or two tests, when the piston rod or plunger was found to leak steam. At the boiler end, the flue gases were analyzed, and it was found that under normal conditions the combustion was quite complete. The gases left the main flue at a somewhat high temperature, and this, notwithstanding that a feed-water coil was installed just back of the main damper. In the hope of reducing the temperature of the escaping flue gases, 18-in. bafflers were then introduced into the fire tubes, but with no avail, as might have been expected, since they merely retarded the velocity of the gases of combustion and, consequently, reduced the supply of heat.

Some twenty tests, in all, were made with this plant, and it seemed as though nearly every means had been tried to locate any defects and to make corresponding changes to remedy them. On the whole, the pump itself was of ample design. The passages to and from the pump were too small, and were remediable only to a degree, as a portion of the suction pipe was cast with the pump casing. The cylinders were of proper dimensions, but the clearance spaces were too large, and resulted in an extravagant waste of steam, aggravated also by high piston speed. In fact, not until, in addition to the many other changes, these cylinders were replaced by new ones having different valve motion and less clearance did this pump finally fulfill its requirements.

Among the points which impressed the writer during his studies in connection with this pump, in regard to, not only the design, but also the testing of pumps, might be mentioned the following:

1.—For high efficiency, and consequently duty, the lower the velocity should be, low not only in the pump, but in the suction and discharge passages.

2.—That, as far as the efficiency of a wheel is concerned, there may be allowed, within certain limits, some latitude as to the radii of curvature of the vanes and their angles with the inner and outer circumferences of the wheel; the result of changes in these elements being to increase or diminish the rate of speed for the point of maximum efficiency for a wheel of any given diameter.

3.—That, for a given rate of discharge, the larger the wheel, the slower the velocities and the less the losses within the wheel.

4.—That, in specifications concerning the testing of pumps, it should be stated most clearly just what constitutes the working lift and just how it should be measured; that is, whether the head is dynamic or static, and between what points in the suction or discharge passages it should be measured.

Mr. Horton.

5.—In order to afford a more uniform comparison between tests of different pumping plants, it is better to measure the lift between points on the suction and discharge as near the pump as practicable.

6.—As the curves of efficiency and duty, with constant lift, and in terms of the rate of discharge, are such that the maximum points are at a rate of discharge much below the maximum capacity of the pump, it follows, that, in order to obtain high efficiencies and duties for specified rates of delivery, there will be necessarily a spare capacity beyond these rates which may be available at a relatively lower efficiency and duty.

7.—It follows, from the previous paragraph, that in drawing specifications, especially for sewage pumps, it might be more economical to specify that the pump shall have a certain capacity according to the maximum work required, but that the required duty and efficiency shall be for a lower rate of discharge. The pump will then not be too large, and the higher efficiencies will be realized for normal working conditions.

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SOUTH AFRICAN IRRIGATION.

Discussion.*

By AUGUSTINE W. WRIGHT, M. Am. Soc. C. E.

Mr. Wright. AUGUSTINE W. WRIGHT, M. Soc. C. E. (by letter).—The writer is pleased to note that the attention of this Society has been called to the agricultural point of view in irrigation, by Mr. Johnson's paper. As far as the writer's information extends, no paper before this Society, and hardly any engineering reports, dwell upon this subject from the point of view of the farmer.

In Southern California farmers are dependent upon sunlight, irrigation, and bacteria for all their fruits.

Considering these factors *seriatim*, the writer will first deal with sunlight.

Quoting from Professor King's book, "On The Soil," which it is hoped is familiar to all, he states:

"It is very essential that we firmly grasp the important part which both direct and altered sunshine play in plant growth; for while we have no control over the amount which may come to a given field, we can and do control the amount stored in the soil, and we also determine the number of plants which shall stand upon the field and utilize the sunshine which does come to it. * * * So powerful is the work of the sun against the cold ether of space, that Lord Kelvin estimates it at 133 000 H.-P. for each square meter at the sun's surface, and the working capacity of a cubic mile of sunshine, near the surface of the earth, he places at nearly 22 H.-P. Now, since the cubic miles of sunshine are arriving at the rate of 186 680 per second, each square foot of the earth's surface receives about one-seventh horse power."

Farmers are blessed with an abundance of sunlight in Southern California.

*This discussion (of the paper by Francis Robert Johnson, M. Am. Soc. C. E., printed in *Proceedings* for August, 1903, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. Communications on this subject received prior to November 27th, 1903, will be printed subsequently.

Mr. Wright

As to the question of irrigation, the writer is of the opinion that, as a rule, too much water is used in Southern California. All know that, of the two evils, too much water is worse than too little. It drowns the tree just as effectually as water would drown a human being. Hellriegel places the amount of water which should drain away from the soil, before it becomes habitable by cultivated plants, as high as 40 to 50% of their full capacity.

Professor King, speaking of the part played by water, says:

"Finally, with the advent of living forms upon our planet, water took up still another very important work; for to both plants and animals it is indispensible. Making up the larger part of their weight, it is the medium in which the chemical transformation, essential to the processes of growth takes place, if, indeed it does not play the part of an active and indispensible agent in bringing these changes about. Then, too, water not only takes up and holds in liquid form those substances in the soil which may become the food of plants, but it is a medium of transportation by which all materials are moved from root to leaf and from leaf back to the various places where the processes of growth are taking place. In the physiological processes of the animal body it has a similar and equally important role to play; for here, too, it becomes first a solvent and then a medium of transportation by which all food is taken to and the waste removed from the various organs of the body.

"Finally, both in plants and minerals water acts as a temperature regulator, tending by its evaporation from the surface to prevent the bodies becoming too warm, and among many animals this action is very marked."

Water being expensive in Southern California, for it is called worth $1 000 per miner's inch, or $100 per miner's inch per annum, the user is prone to take all he can get. The amount he can use beneficially is unknown to him.

Farming is becoming day by day, more of a science, and the number of bright minds now engaged in solving its problems is greater than ever before in the history of the world.

From their investigations, the quantity of water required for various crops is now known. Professor King estimates the number of tons of water per ton of dry matter needed in Wisconsin for the following crops, as:

Dent corn....	309.8 tons.	Oats	522.4 tons.
Flint corn....	233.9 "	Field peas...	477.4 "
Red clover...	452.8 "	Potatoes	422.7 "
Barley	392.9 "		

Hellriegel found, through experiments conducted in Prussia, that the quantity of water withdrawn from the soil, and given to the air, almost wholly through the plant, was as follows, for each pound of dry matter produced:

Barley.....	310 lbs.	Horse beans.....	282 lbs.
Summer rye.....	353 "	Peas.....	273 "
Summer wheat..	338 "	Red clover.....	310 "
Oats	376 "	Buckwheat.....	363 "

Mr. Wright. This is at the rate of 325 tons of water for each ton of dry matter produced.

Proceeding to the consideration of bacteria, and quoting Professor King again:

"We come now to consider one of the most important discoveries of modern times, a discovery which places in the hands of every farmer a means, completely under his control, whereby he can at any time cause to be drawn directly from the atmosphere, the free nitrogen of the air, and have it fixed in the soil of any field he may wish to enrich. In 1888, Hellriegel published the results of his experiments, which satisfactorily proved the work in the soil done by bacteria."

Professor Cohn, writing of bacteria, but in relation to human life, stated:

"Way down below the limits of the human vision, exists the world of bacteria. So minute are these beings, that only high powers of the microscope reveal them, and they have been known a couple of centuries to exist, before there was any suspicion of their relation to our health. Only the last thirty years have disclosed their bearing on disease. * * * Their number is beyond conception, and their powers of reproduction are scarcely credible; so great indeed are the latter that in many cases a single individual may produce sixteen million of offspring in twenty-four hours."

To-day, thanks to the researches that have been made, the important part taken in all farming operations by bacteria is known. Given every other requirement, the farmer could grow no crop without the friendly co-operation of the minute bacteria. They enter into everything. All decay is due to their action. While some bacteria can endure several thousand degrees of heat, others can endure cold below freezing; but the greater number of the bacteria of decay are rendered inert at from 185 to 212° Fahr. If the article to be preserved be heated to the necessary temperature, and then sealed, so as to prevent the entrance of bacteria—ever present in the air—the article will be preserved for years. This is the foundation of all canning and preserving methods. These bacteria of decay are also rendered inert by a temperature approximating freezing, and this discovery has led to the investment of nearly $200 000 000 in cold-storage plants in the United States. The use of this process has saved the sheep interests of Australia from impending ruin, and the carcasses of their sheep are by this method transported to Europe, and sold at a price that enables many of the poor to indulge in the luxury of meat which, otherwise, they could not taste.

Captain Field, of the United States Navy, has told the writer that a steamer transports ninety thousand carcasses of sheep on one voyage! Figure the train capacity this represents!

The flavor of each variety of cheese is now known to differ, one from the other, because of bacteria. The varying flavor of tobacco is due to the same cause; and the Government, by introducing the bacteria

of Cuba into the Connecticut River Valley is duplicating the flavor of the Cuban tobacco. Mr. Wright.

If one knew how much water the soil contained, he could measure the rainfall, and knowing the amount needed for his crop, he could put on the proper quantity, instead of "guessing" as at present.

Two years ago, the writer asked Professor Wiley, of the Agricultural Department at Washington, if the electrical method of soil moisture determination was applicable to the arid region. He replied that it had not been tested in the arid region, but, in his judgment, it was not applicable to those conditions. Had it been applicable, the writer would have used it, and thereby measuring the moisture in the soil would have had a better basis on which to estimate the quantity of water needed. At present, a miner's inch (12 960 galls. in 24 hours) is used for 8 acres of citrus fruits. Most of the fruit trees in Southern California are planted at 20 ft. from center to center each way—about one hundred and ten trees to the acre.

Of course, the field is graded before any trees are planted. As pointed out by Professor Hilgard, the arid region really consists of three farms, one on top of the other. The writer has seen an excavation, 60 ft. in depth, with the same soil at the bottom as at the surface. In the grading for a ranch in Southern California, the hills are scraped down to fill the hollows. This condition is entirely different from that of the humid region. There, one encounters subsoil in which nothing will grow until it has been turned up and exposed to the "weathering" effects of wind, frost, and air for months. When a root reaches the subsoil in the humid region, its progress downward is stopped—it must spread laterally. Not so in the arid region. It is this difference in soil that permits the enormous crops to be grown in California. It is claimed that Alfalfa roots have been traced more than 100 ft. Its enormous spread of roots enables it to seek food, so that 24 000 lbs. are frequently cut from an acre within twelve months. The writer has known lemon trees to produce, within twelve months, 750 lbs. of fruit, or 8 250 lbs. per acre.

The irrigator prefers a good head of water, say 30 ins. or more, If the stream is small, and the soil at all sandy, the trees where he starts irrigating get more than their share, as the water sinks into the ground before the lower end of the field is reached.

Two systems of irrigation are in vogue. In one system, three or five furrows are plowed between each row of trees, and the water is turned into one furrow after the other until the field is irrigated.

In the other system, ridges are thrown up dividing the field into squares of 20 ft., and one square is filled, and then another, until the field has been gone over. It is obvious that this system allows better control of the water; but, on the other hand, if the water be allowed to stand in these compartments, diseases will develop in the tree.

Mr. Wright. "Now, the water placed upon the field may break away and run off; it may be lost by circulating downward beyond reach of root action, or it may be lost by surface evaporation from the ground itself. As a rule, it is only that water which really passes through the plant which contributes materially to its growth."

Recognizing this fact, it is customary to cultivate the field just as soon as it is dry enough, for it has been found that fine earth on the surface retains moisture in the soil in the best practicable manner.

It must not be forgotten that the soil must be pervious to the air otherwise, nothing will grow. It is customary in Southern California to irrigate each three weeks during the dry season.

When one considers that, with a large crop, Southern California ships thirty thousand carloads of oranges and lemons alone in twelve months, on which she pays the railroads nearly $10 300 000 in freight, the importance of this industry will be realized; and the importance of irrigation to so many localities not now served.

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SEWAGE PURIFICATION.

An Informal Discussion at the Annual Convention, June 10th, 1903.*

By L. J. Le Conte, M. Am. Soc. C. E.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—Sewage purification is rapidly becoming a matter of grave public importance, and calls for a high type of intelligent supervision in order to insure good results. Mr. Le Conte.

In the younger States of the Union, the population being sparse, the question of stream pollution does not arise, but as the population increases and manufacturing establishments begin to develop, the pollution troubles begin to show themselves, and endless complaints are duly filed, and end in the Courts with suits for damages sustained.

The oldest and most densely populated State in the Union is Massachusetts, and there the troubles regarding stream pollution are most pronounced. Hence, when troubles of this nature arise in a younger State, one turns naturally to the old Bay State for advice and counsel as to the future requirements which are likely to be enforced by the Courts.

The State Board of Health of Massachusetts has been and is now spending large sums of money in quietly experimenting—on a commendable scale—to find the true value of the different methods of

*The discussion of this subject, on which no formal paper was presented, is continued from the September, 1903, *Proceedings*.

Mr. Le Conte. sewage purification. These results are published in their annual reports, which really constitute some of the very best information available on the subject.

In a general way, it may be said that when a natural stream becomes highly polluted at low stages, so as to become an intolerable public nuisance, then some palliative action must be taken to remedy the evil. Hundreds of devices have been tried, but with indifferent success. Probably the most practical methods are:

First.—By percolation through porous soils, or sand—being, in short, broad irrigation—the purified filtrate passing into the stream. This method, necessarily, calls for a large tract of land of suitable character, which is seldom available.

Second.—By preliminary treatment, such as settling, septic action, chemical precipitation and filtration through coarse material, in order to reduce the quantity of suspended matter as well as the dissolved organic matter, both being preparatory to a final treatment, either by dilution or by intermittent filtration through porous soils. By this last method, the acreage required is very much reduced.

After the sewage has passed through tanks providing subsidence and septic action, it may be turned into the stream, always bearing in mind that the sewage from one thousand people may be safely diluted by a river flow of 4.0 cu. ft. per second. Such disposal will be quite inoffensive when discharged in the middle of the stream. The remainder of the sewage, over and above this amount, must go to the intermittent filter beds, the purified filtrate from which may also be discharged into the river almost anywhere. If this is done properly, and the details are attended to faithfully, the results will be highly satisfactory.

In cases where suitable land is not available, it may become necessary to construct the entire filter beds artificially, which will add very materially to the first cost and to the maintenance.

Of course, each particular case calls for a special study in itself, in order to get the best results with the least expense. This, after all, is the main result to be attained, and, in order to be reasonably sure of obtaining it, a competent expert should be engaged to study the case.

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THE LEVEE THEORY ON THE MISSISSIPPI RIVER.

An Informal Discussion at the Annual Convention, June 10th, 1903.*

SUBJECT FOR DISCUSSION:

"In the Treatment of the Mississippi River, is the Levee Theory Justified by Experience?"

By Messrs. B. F. THOMAS, HENRY B. RICHARDSON and B. M. HARROD.

Mr. Thomas.

B. F. THOMAS, M. Am. Soc. C. E. (by letter.)—This question can hardly be answered if we are to consider the experience on the Mississippi alone, because the works are not yet complete as to extent, height or section; but we are at liberty to investigate the effects of such works in other countries, and draw conclusions from their experience of more than twenty centuries, because levees are among the most ancient works which have been executed on watercourses, having been constructed by the Egyptians, Babylonians, Phœnicians, Romans and East Indian nations along the Euphrates, Tiber, Po, Arno, Chiana, Adige, Reno, and other streams.

The question of how best to remedy the evils incident to the succeeding inundations of fertile valleys was discussed by some of the greatest philosophers of the past, among whom were Galileo, Poleni, Torricelli and Zendrini, and this discussion resulted in the establishment of a general levee system. Later came similar systems along the Rhine, Oder, Elbe, Theiss, Vaert, Thames, Mersey, Loire, Vistula, Mississippi, and other rivers of importance. In the ancient discus-

* The discussion of this subject, on which no formal paper was presented, is continued from the August, 1903, *Proceedings*.

Mr. Thomas. sions, three methods of caring for the excess of flow were considered. These were:

1. To give the promptest discharge possible, so as to pass the waters as fast as they arrive.
2. To retain the flood waters, so as to prolong the duration of the flood, but reduce its intensity.
3. To allow the flood a sufficient space, but circumscribed, in which the discharge will be effected according to its laws, and outside of which the soil (sheltered by levees) will not be subject to inundation.

The first is the clearing process; the second the storage reservoir, and the third the levee system.

Clearing.—Clearing consists of the removal of all obstructions, and straightening and widening the river bed. It does not constitute a remedy, in so far as it affects the principal stream, but, when applied to the side streams in the lower part of a valley, it enables them to discharge their waters more quickly, so that, theoretically, the lower tributaries will have been emptied before the flood arrives from above. However, this result is not always accomplished, because the tributaries will not always rise at the time desired, and because, as the sea is approached, the slope is diminished and the velocity becomes less, so that the bed is not capable of discharging the increased flow precipitated upon it, and overflow is bound to result in the lower part of the valley, usually the most fertile and thickly populated. Where this method has been adopted, the conclusion has been reached that:

"It may be a palliation of the evil over some special points or obstacles raising the flood, but not a remedy for inundations in general, and that, sufficiently generalized, it tends to aggravate rather than lessen the effects of floods."

Storage.—Directly opposite to the foregoing are the results aimed at by the method of storing flood waters and allowing them to escape gradually as the flood subsides, or even holding them to assist navigation during low water.

A striking example of the effect of reservoirs on floods is given by Lombardini. The maximum discharge of the Adda, in the flood of September, 1829, at its entrance to Lake Como, was 68 501 cu. ft. per second, while at its exit it was only 28 389 cu. ft. In passing through the lake the maximum flood was diminished in the ratio of 2.4 to 1. This suggests the creation of artificial reservoirs in which to hold the waters during flood times, and this seductive idea has taken strong hold on many engineers of ability, only to be dropped from consideration when its utter impossibility, within reasonable cost, became apparent. Leaving the cost of establishment out of the question, the cost of removing deposits which accumulate constantly, the danger of disaster from breaking when full, a danger far greater than can be expected from extraordinary floods, and the fact that the reservoirs

will not always be empty at the opportune moment, ready to catch the waters as they come, must render their adoption unwise and inexpedient, unless other questions of great importance are involved; for instance, if there are groups of interests justifying the establishment of large storage, it might be well to increase the capacity for the purpose of preventing serious overflow. Mr. Thomas.

The writer believes that it is only necessary to study thoroughly the reservoir question, as applicable to the Mississippi problem, to convince anyone that it is impracticable, or even impossible.

Levees.—If one will observe an overflowed valley he will find that over the greater part of its transverse profile a much larger area is being covered than is required for the river's discharge, and that the water is quiet for a great distance on either side of the main river bed. He will at once conceive the idea of confining the water to the space necessary for its flow and sheltering the adjacent lands from inundation, and the many disasters and inconveniences caused thereby. The embankments by which this is effected have received the name of levees. Their use dates from all antiquity, and has made possible the building up of rich kingdoms in districts which, otherwise, would have been uninhabitable.

The oldest example of importance, that of the Po, has assured the protection of a vast and rich territory century after century, and still stands as a monument to the skill, perseverance and foresight of Italian engineers, men who dared to act in the face of strenuous opposition and fierce calumny. These embankments follow not only the main stream, but turn up each side of the affluents to points where overflows will not reach, so that:

"The vast submersible plain of the Po is guarded by an immense network of dikes enveloping each stream and defining for all, without exception, a bed in which is concentrated the escape of the floods of the valley."

These levees have been so spaced at and near the mouths of tributaries of importance that the "major bed forms a sort of reservoir in which is stored not only the floods but still, and to disappear with time, the deposits carried by the affluents." In this way the major bed of the main stream and of its affluents in their lower part serves as a regulator for floods, descending from the mountains, which are led out to the sea by a "contracted outlet that tempers the velocity and the disastrous effects by bringing about the raising of the flood above the Panaro." Lombardini has stated, and it has been confirmed in the report of Baumgarten, that this equilibrium has been happily established, so that the discharge is virtually the same at Tessin, Cremona, and toward Ferrara, and that, while the combined discharge of all the affluents amounts to 528 000 cu. ft. per second, the discharge of the Po during the same period is only 176 000 cu. ft. per second. This is certainly a remarkable result, and doubtless much of it must be attrib-

Mr. Thomas. uted to the fact that the tributaries do not discharge flood waters simultaneously and that the lakes retard the flow to a marked extent.

The volume of water stored between the levees of the Po and tributaries, from Casale to the sea, is given as 1 896 000 000 cu. m., a quantity corresponding to more than four days' discharge of the river at the rate above given. Thus there has been created an artificial reservoir, the effect of which is the same upon the Po as is that of the lakes upon some of its tributaries, and in this fact lies the secret of their great success. There are, however, very serious drawbacks to levees as a means for preventing inundation, and Belgrand has stated that:

"It is plain that even in a country where levees have existed for twenty centuries, where property has been exposed to all the consequences—the valley of the Po—it has not been clearly demonstrated that the advantages are greater than the inconveniences."

The chief objections to levees are: (1) that they raise flood heights; (2) that they break too easily and often; (3) that they cost too much; (4) that they cause the river bed to rise because they do not permit the escape of sediment over the banks.

Levees undoubtedly do raise flood levels. Here are the proofs: Some thirty years ago Chief Engineer Dausse made the statement that the level of the highest water of the Po had increased about 2 m. in two centuries, and that while there were only forty-one breaks of levees in the 18th century there were one hundred and nineteen in the first seventy-two years of the 19th, 1872 alone having thirty-six.

On the Theiss, at Szégédin, the following heights have been observed since the levees were built:

1845	21.0 ft.
1855	22.8 "
1867	23.6 "
1876	25.7 "
1888	27.8 "

On the Loire, the coping was originally placed at 15 ft. above low water. After the flood of 1706 it was raised to 21 ft., and in 1846 to 24 ft. Even at that height, the floods of 1856 and 1866 went over in many places, involving most disastrous consequences.

On the Mississippi, the record at Carrollton, La., is as follows:

1828	14.85 ft.
1851	15.05 "
1874	15.35 "
1897	18.72 "
1903	19.05 "

The completion of the system will undoubtedly be the signal for higher flood levels, and the struggle to hold the water within bounds will continue indefinitely. It will not always be possible to prevent

overflow, but, in the main, intelligent effort will meet with success, and, while there will always be a feeling of insecurity, yet the conditions will improve with time. A levee is not a perfect barrier against inundation, but it is without doubt the best that can be obtained at reasonable cost. Mr. Thomas.

The second objection noted, namely that levees are unsafe by reason of the ease with which crevasses may be made, is based on conditions which can only be eliminated by care in construction and maintenance at present, and by increase of height in the future, as found advisable.

Levees fail, generally, from insufficient height; sometimes from leakage, sloughing, wave wash, or malicious cutting; but, as a rule, because they have been overtopped by the water.

The objection of cost has no reasonable foundation in fact, because the levees in this country are less expensive by far than those abroad have been, and their final completion and placing in good order does not mean the expenditure of a great amount of money, when all the benefits to be derived from a good and safe system are considered. There is no other means by which overflowed lands can be reclaimed at such a small expense, and the writer is glad to see that there is a general realization of the importance of the work, and a tendency to more liberal allotments for carrying it on properly.

The charge that the building of levees along a river will cause its bed to rise is contrary to experience and to the laws governing the flow of water, because the very fact that the water is confined in a limited space is an assurance that its velocity will be increased and its transporting power be the greater. Of course, it will have more work to do, because the silt must remain between the levees, but experience proves that the work will be done.

Outlets.—Much has been said and written in regard to carrying off the excess of floods through artificial outlets, but those who have given the subject most thought and those who are responsible for the execution of the projects have long since concluded that the method is not practicable for the Mississippi because there are no advantageous sites, even if the theory is correct, which is an open question. The writer has not noticed this feature discussed in connection with the establishment of foreign systems, so that he thinks it probable that the conditions there are not favorable to its use. The principal advantages and disadvantages of this method have already been given in this discussion (pages 726–730*), and nothing further will be added here.

Conclusion.—In 1877 the writer made a journey to Louisiana where he spent several months in the examination of abandoned plantations and timber lands which had been bought, at bankrupt sale after the

* *Proceedings*, Am. Soc. C. E., for August, 1903.

Mr. Thomas. Civil War, by a gentleman in the North. The principal part of the travel was done on horseback, between the Ouachita and Mississippi. At that time the United States had not undertaken to assist in the construction of the levees, and those built by the State were generally in bad repair and of little benefit.

The writer was daily brought in close contact with the suffering, struggling planters, eking out a mere existence on little patches here and there, while all about them were vast acres of rich, alluvial land devastated by the water. They lived in constant dread of an overflow which might ruin even these meager prospects. There was not a blade of grass or bearing fruit tree for miles. Here and there, mounds were thrown up, upon which the cattle had to stand and fight the flies for days and weeks, without vegetation, except that which was boated to them.

Buildings had "run down" or had been destroyed by the war a few years before. Taxes had "eaten them up" under the reconstruction government. Their case was indeed pitiable in the extreme and apparently hopeless. The writer made one journey of more than twenty miles among plantations, some of which had at one time been the pride of the South, without seeing a single human face; even the negro, the ever-present, ever-faithful aid to the southern planter, had disappeared from the face of the earth. He met a small drove of hogs swimming toward dry land, one of which, the leader, had almost cut his own throat by striking it with his feet as he paddled himself to safety.

How changed is all this now! Behind hundreds of miles of levees these people plow and plant, sow and reap, pick cotton, gather fruit, and care for herds of fine cattle, all unmindful of the mighty Mississippi outside. Then they had few neighbors, schools or churches; now these are on every side. The children go to school on foot or drive along good roads, or on the banquette or crown of the levee. All is peace, plenty and happiness where a quarter of a century ago, or less, was despair, almost starvation. If proof were necessary, the changed conditions of the people during this period should be a lasting and sufficient argument in favor of a levee system and of its early completion and permanent preservation by the General Government; and the writer hopes that the good and intelligent people of this country will see to it that public opinion is not led off after strange gods, because a few well-meaning but poorly informed persons are clamoring for something else, their only excuse being that levees do not always and everywhere prevent inundation. Let us as a people hold up the hands of those pioneer engineers, who, although seriously hampered, are working so zealously and intelligently for the general good.

The levee system is not perfect. It never will be as complete as we would desire, but it is far and away ahead of anything else proposed

by its opponents, or, within reason, possible, and it has been well advanced toward completion. It would be the greatest folly to abandon a work so well started, or even use it as auxiliary to an untried system, as proposed by some. The thing to be done, as the writer sees it, is to proceed as rapidly as practicable upon the lines laid down, making such modifications as the experience gained thus far seems to indicate as advisable, and when the system as planned has been completed, to maintain it, strengthen it, increase its height, if need be, extend it where it will be advantageous, correct its early errors of location or those parts rendered dangerous by the encroachment of the river, and in every way make it a perfect barrier against flood water, to the end that those who are to be benefited shall realize it as soon as practicable and be thus encouraged to build up and improve the rich territory protected, and thus recover much that has been lost by weary years of patient waiting, uncertainty and deprivation. Mr. Thomas.

HENRY B. RICHARDSON, M. Am. Soc. C. E. (by letter).—The form in which the question under discussion is stated seems to imply some disagreement or inconsistency between theory and the results of practice in the matter of levee building on the Mississippi River. If there is such thing as a "levee theory" for the Mississippi, it has been deduced from the practice and experience of four or five generations of the inhabitants of its alluvial valley who have been constantly engaged in levee building, in reclaiming the wilderness from savagery and preparing it for cultivation and civilization. The answer to the question, if left to these people who have had this actual and immediate experience in "the treatment of the Mississippi River" would be an almost unanimous "yes." Mr. Richardson.

The aim and purpose of levee building, everywhere, is the control of floods; either to prevent destructive overflow, or to fix and preserve the channels through which the water flows at normal stages.

Theory and practice alike agree that the most direct method for confining the waters in times of flood to the path of their ordinary flow is to raise the banks of the watercourses to a higher level, that is, to build levees along streams which are subject to flood and overflow.

A plan which is supposed to contemplate carrying this obvious method to the limit of completely confining all flood waters to the stream in which they naturally gather is presumably what is meant by "the Levee Theory"; while a plan which proposes the regulation of the volume of discharge by impounding the surplus waters before or after they are concentrated in a single stream, or which proposes the diversion of flood waters in excess of a certain stage, or volume, through auxiliary channels or waste weirs, may be another "theory." The levee plan, however, as far as it has gone, has already been the subject of long experience; while the impounding or reservoir plan, and the diversion or outlet plan, are still in the theoretical stage as regards the treatment of the Mississippi River.

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The undertaking of works, especially of great public works, cannot be justified, if their plan involves a violation of natural laws, nor if their cost will greatly exceed the value of the benefits expected from them; nor, even, if the benefits in one direction are too largely offset by damages in another. No man, for instance, can justly expect, by any combination of cranks and levers or realized vision of wheels, to lift himself over the moon by his boot straps, nor justify an investment in the stock of a factory to extract sunbeams from cucumbers; nor prove the economy of cutting off his feet to save shoe leather.

But the control of floods in the Mississippi, as now practiced by means of levees, has been objected to as an attempt to interfere with Nature's laws. Poets and prophets are cited to show the disasters that must follow the prevention of overflows, and the necessity for irrigation in Egypt is instanced as a reason for condemning the application of a levee system to the Mississippi.

It is certain that in a state of nature all the alluvial valley was subject to frequent overflow, and that while thus laid under water it was unfit for the habitation of man, for agriculture, or for most of the occupations and arts of civilized life. But why it should be a more heinous crime against Nature—even in the eyes of the prophets—to reclaim the wilderness for the uses of man by preventing inundation, than to make the desert fruitful for him by artificial storage and distribution of surplus waters, is not apparent to the uninspired mind. Both of these great undertakings are attempts to modify the course of Nature as it would proceed without the interference of man, and have been carried on in one place or another from time immemorial with great success and benefit.

The fact that the fertility and prosperity of Egypt depend upon overflow or irrigation from the Nile has little application to the condition of the alluvial basins of the Mississippi. The valley of the Nile below the cataracts is generally arid, and is swept by the dry, hot winds of the adjacent deserts. In upper Egypt rain is almost unknown, and in the delta north of Cairo it is rare and scanty. The alluvion of the Mississippi, on the contrary, is bordered by an amply watered and timbered territory, and receives a copious and well-distributed rainfall. Although irrigation is often beneficial, and always necessary for the cultivation of rice, it is readily obtained by gravitation during the high-water season, and by pumping at other times. But agriculture, here, suffers more frequently from the ground being too wet than from being too dry. Drainage and protection from overflow are the greatest needs for the successful cultivation of the soil.

The contention that the bed of the Mississippi is filling up with sedimentary deposits, and thus becoming a less efficient channel for the discharge of its flood waters, and for the needs of navigation, is not borne out by the experience of navigators, nor by the results of

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the innumerable direct measurements that have been made in the surveys of the river. Those parts of the stream where levees have been longest and most effectively maintained, have the best and most capacious channels. If it were true that the bed of the river is silting up, it would still remain to be shown and explained how and why the levees have had anything to do with it, except as a preventive.

It is said that in its natural condition the flood waters overflowing the river banks deposited their silt on the adjacent lands, greatly to their enrichment and improvement, which is true enough; but the inference that the silt thus deposited on the land would have been thrown down on the bed of the river had the flood waters not been permitted to escape, is not even plausible. From what natural law can it follow that a stream of sediment-bearing water with a volume of, say, 1 000 000 cu. ft. per second should fail to deposit silt in its channel, but that when increased in volume by 50%, or more, it must at once begin to drop its burden all along the road? If the stream were an ox or an ass, one might comprehend it; but, in a river, it seems not contrary to natural laws that the larger the volume—other things being the same—the more silt it will be able to carry. The experience of anyone familiar with the Lower Mississippi River should show that when it is in flood it generally carries its heaviest load of silt per unit of volume. When the discharge is greatest, the water is always muddy, and when it is least, the lower river is usually comparatively clear.

But will the cost of a levee system on the Mississippi be a profitable financial investment? If the game is not worth the candle, it has no economic justification. The area of the alluvial valley subject to overflow south of Cape Girardeau is reckoned at 29 790 sq. miles, or, say, more than 19 000 000 acres. Making the very moderate assumption that only one-half of this area will be made to yield agricultural products, when protected from overflow, to the value of only $1 per acre per annum, in excess of what it would have yielded without such protection, there would be gained a yearly revenue sufficient to pay 3% interest, plus 2½% for maintenance, on an investment of, say, $175 000 000; which is nearly ten times the estimated amount now required to complete the levee system. Considering that the land is practically worthless as a source of agricultural profit when not protected from overflow, and that when so protected it ranks among the richest and most fertile in the world, there can be no question as to the profitable results that must follow its protection.

The man who lives and carries on his business in the low lands behind a levee is subject to a kind of danger which does not threaten those who live on the hills, and "they that go down to the sea in ships" incur perils impossible to the man who keeps ashore. But ship building, and ocean travel and commerce, will not cease because

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a few vessels are foundered or wrecked, nor will levee building be abandoned because of occasional crevasses and overflows; for ship building and levee building appear to be equally justified by experience.

The dual or multiple channel theory of treating the Mississippi River, which proposes to divide it into two or more parallel streams, would increase immensely the length and quantity of levee construction necessary to prevent overflow, because the diverted streams must flow in channels bordered by very much lower land than that near the banks of the main river. Moreover, if the present drainage channels are to be occupied by the diverted flood waters, other channels must be made to drain away the seepage and rain water. The cost of such a system, even if it were possible of application, would apparently prohibit it. The experience with even such leveed outlets as exist, or have existed, although their natural banks are high, has been that larger and larger levees have been required to prevent their overflow; so that Bayou Plaquemines was closed forty years ago, and most practical observers are now convinced that the enormous outlay required to keep up levees on Bayou Lafourche would better have been expended on the levees of the Mississippi, and that this bayou also should be closed, so that the levee funds now required there may be made available for work on the levees of the main river.

The deficiencies and imperfections of an unfinished structure do not justify condemnation of the theory upon which it is designed. The levee system of the Mississippi is still far from completion, and, like other works in progress, must suffer its share of reverses and accidents, and, for the time being, fail to supply the full measure of benefit expected from it.

There are doubtless many defects in the existing levee systems, some of them hidden or unknown, and others plainly evident; but it is not unreasonable to expect that, in the process of time, the concealed faults and dangers may manifest themselves, and be eliminated as the work of improvement in grade, section and location progresses.

To say that "the river by breaching its ramparts with each successive flood enters its solemn and devastating protest against interference with the designs of Nature," is a figure of speech quite as applicable to the locomotive of a construction train that jumps the rails of an unfinished railway, and should be equally convincing in either case.

Some of the criticisms as to faulty location may possibly arise from imperfect knowledge of the situation. Fig. 4, which shows the alignment of levees for some 200 miles above Vicksburg, may give erroneous ideas to one not familiar with the actual topography. The succession of lakes and gorges that might be inferred from the figure does not exist in fact, as far as the channel of the river is concerned. The ex-

cessively wide places between levees are, in almost every case, covered with trees and underbrush, and frequently have levees—not shown in the figure—that prevent flow except along the course bounded by the natural banks of the river. The places where levees on either side are close together are not gorges in the sense of confining the current to materially narrower limits than it occupies in the wider places. The path of the principal current, both at high and low stages, lies within the tract shown by water lines on the figure. An examination of the ground would probably indicate to anyone that the setting back of levees at the so-called gorges would make little difference in the capacity of the channel for carrying or discharging its flood waters. Mr. Richardson.

Whether or not experience with tubes of 3 mm. diameter—or even with those of such large diameter as 11 mm.—can justify a theory for the treatment of a stream like the Mississippi River may be questionable; but it is a question which, perhaps, may best be left for future discussion by the Society.

B. M. HARROD, Past-President, Am. Soc. C. E. (by letter).—The national character and importance of the great work which is the subject of this discussion merits an interest and understanding on the part of civil engineers which it has not generally received, but to which, it is hoped, the present discussion will contribute. In closing, attention must be given to the discussions taking a critical attitude toward the adopted plan, as well as the general features of the river, and the project for its improvement. Mr. Harrod.

Mr. Brown's discussion is of wide range. It covers the physical history of the alluvial valley, the intentions of Nature for its further development, the way in which these have been thwarted by man, the present condition of the valley and river, and a plan for future improvement in which the forces of Nature and the skill of man will combine and co-operate.

The views concerning the past and intended future history of the valley have the quality of originality. Their general discussion may be left to the geologist and physical geographer, but reference to one or two points is opportune here.

Mr. Brown has observed:

"That the river hugs the high country on the east side of the alluvial embayment throughout its whole length, from the mouth of the Ohio to near New Orleans, excepting between Memphis and Vicksburg, and that the tendency of the river throughout is to hug or parallel this higher or older territory on the east."

As the exception mentioned, from Memphis to Vicksburg, where the river is not under or near the eastern bluffs, but wanders across the alluvial plains, is 45% of the length under consideration, or 370 miles out of 830, the "tendency" to hug the high country on the east is not very well defined. But as this higher eastern formation extends to the Gulf, and as the river, by following it, would find a shorter

Mr. Harrod. route to the sea through Lakes Maurepas and Pontchartrain, it appears that, notwithstanding this tendency, the river leaves the eastern and northern limit of the valley for 620 miles out of 1 080, or 57% of its length from Cairo to the Gulf.

The reasons he assigns for this alleged phenomenon are: That the tributaries entering the main trunk from the east have a velocity and abrading force for cutting their channel through the alluvium superior to that exerted by those from the west, due to the greater age, height and abruptness of the eastern hills; that the action of these eastern tributaries is to abrade more rapidly the banks on that side, and, generally, that the western bank has been subjected to less abrasion and wear from its tributaries.

To this it must be answered that exact measurements have shown that erosion is now greater on the western than on the eastern bank; that the superior energy of the tributaries from the east is not, in any way, apparent; that no observations have ever connected the entrance of tributaries and the recession of the banks on the side from which they enter, as cause and effect, and that, if such connection does exist, the result would be a movement of the main trunk toward the west, instead of the east, since all the important tributaries below Cairo, with a single exception, enter the main river from the west, with a volume, energy and duration of flood stage many times greater than that of those from the east. The drainage area on the west extends to the Rockies, while the divide on the east runs through Kentucky, Tennessee and Mississippi, States bordering on the Mississippi River.

The reasons are not apparent why the Lower Mississippi alone, of the rivers of North America, should be charged with breaking Ferrel's law that:

"If a body moves in any direction on the earth's surface, there is a deflecting force arising from the earth's rotation which deflects it to the right in the northern hemisphere, and to the left in the southern hemisphere."

Russell says:

"There is a slight tendency throughout the length of every stream of North America, and at all times, to erode its right bank more rapidly than the left bank."

He illustrates this by the streams on the south side of Long Island.

"Each of the little valleys is bordered on the west or right side by a bluff, while its gentle slope on the left side merges imperceptibly with the general plain. The streams, in each case, follow closely the bluff on the right."

In the case of the Mississippi, Gilbert states that the tendency toward the right bank is nearly 9% greater than toward the left bank, and measurements of caving banks, made by the Mississippi River Commission, confirm this observation. However this may be, the effect must be so slight, and its cause so cosmic and uncontrollable, that it cannot enter, as an important factor, into a plan for the im-

provement of the river. The indirectness of its course, both in the local and minor bends, and in its grand sweeps from side to side of the valley, is accounted for simply and satisfactorily by the fact that the length of the plain is too short for the river. If, at any time, or for any reason, the course of the stream was directly from Cairo to the Gulf, or only about 560 miles long, the slope and velocity could not be maintained, as it would immediately set to work, as alluvial streams always do, to establish meanders, thus increasing its length and reducing its slope and velocity to some sort of an adjustment with the resisting quality of the material through which it flows. Mr. Harrod.

The limit of this discussion forbids the presentation of a plan for the reclamation of the alluvial valley as extensive as that of Mr. Brown, except in its general outlines, and these alone can now be considered.

It provides for an artificial or "secondary stream," between parallel levees, near the hills, and enclosing the lowest lands of each of the great basins. This is to have a discharge capacity of about 600 000 cu. ft., or 40% of a flood volume assumed at 1 500 000 cu. ft. per second. It is to take its source or supply through the right bank of the first western bend of the Mississippi, above Cairo, and, after cutting through several high ridges, and then following the lowest lands of the St. Francis Basin, is to discharge again into the main river, through the present mouth of the St. Francis River, above Helena, or about 315 miles below its source. There will then be a discharge in the Mississippi, at flood stages, at the point of outflow and of return flow, of 1 500 000 cu. ft., and at intermediate points, of 900 000 cu. ft. per second. The "secondary stream" is to recommence on the opposite, left or eastern side, presumably at Yazoo Pass, and, after following along the lowest lands of the Yazoo Basin, redischarge into the Mississippi about 280 miles below, through the mouth of the Yazoo River, above Vicksburg, with differences of discharge similar to those in the first section. The third section begins again on the west side of the river, and, starting nearly opposite Vicksburg, is to join Red River and then seek an outfall in the Gulf along an undescribed route.

On either side of these sections of the "secondary stream" are to be built cross-levees, forming reservoirs to control the discharge; and "suitable waste weirs, of proper proportions, at such points as may be found necessary" to distribute sediment and thus raise the low lands in the interest of agriculture and sanitation.

As this proposed plan for the improvement of the valley and river, by means of a secondary stream, and other supplementary, but extensive works, is in three sections, divided by the main river, an examination of the first, in the St. Francis Basin from Dogtooth Bend to Helena, will suffice, as the two other sections present substantially similar features and equal difficulties and costs.

Mr. Harrod. Connected at its intake and outlet with the Mississippi, and having a course of nearly the same length as the Mississippi from the Ohio to the St. Francis, the flood surface at start and finish, and at intermediate points, in both streams, main and secondary, in the same latitude, or at proportionate distances from the source, will have the same elevation. What these elevations would ultimately be in the main channel if the flood discharge never exceeded 900 000 cu. ft. per second need not be discussed here. Possibly Mr. Brown assumes that they will always be the same as are now reached by a rising river when the discharge acquires that volume, and that this condition will be permanent. But notwithstanding the violent contradiction of the accepted theory of sedimentary or alluvial rivers involved in the assumption that, if the flood discharge is reduced 40%, the channel capacity will remain undiminished indefinitely, it may now pass unchallenged, for argument's sake.

A flood discharge of 900 000 cu. ft., on a rising river, when passing through the section under consideration, reaches an average bank-full stage, and, were it not for the levees, would be overflowing at many places in large quantities. Trans-alluvial levels show that in the interior of the basin which the proposed plan indicates as the location of the levees, or artificial banks of the new stream, the elevation of the low lands averages about 17 ft. below bank height, or the stage of the main river when the discharge is 900 000 cu. ft. per second. Allowing 3 ft. of free height above this elevation for a safe construction grade, it is found that the new levees of the secondary stream would require a height of about 20 ft., and that the levees now existing on the main river would require no additional grade.

The double line of levees of that part of the secondary stream in the St. Francis Basin, therefore, would have a length of not less than 400 miles, an average height of 20 ft., and contents of 124 000 000 cu. yds. This is more than two-thirds of the contents of the entire levee system, as it now exists on both banks of the river below Cairo; more than is estimated as necessary for its safe completion; and about ten times as much as will be required for the completion of the levee system of the St. Francis Basin, to which consideration is at present confined. Yet, in arriving at this estimate of one section out of three in the writer's plan, an admission is accepted which hydraulic engineers will generally reject, and no allowance is included for cross-levees, forming reservoirs, "suitable waste weirs at such points as may be found necessary," and for the installation and operation of pumping machinery which will be required when the natural drainage is destroyed.

The natural drainage systems of the great basins lying on either side of the river as it meanders across the valley are well developed, and serve satisfactorily the area now under cultivation, except in the

lower region of Louisiana, where rice and sugar cane are benefited by irrigation and artificial drainage. They, however, are susceptible of great improvement by such ditching and the removal of obstructions from natural watercourses as can be here, and is elsewhere, readily accomplished by corporate, if not by individual, effort. Such progress is now being made in many localities. In this way, not only can the cultivable area be very greatly extended, but the production of each unit can be materially increased. The minor drains are tributary to a main trunk, which, following the lowest levels between the high banks of the river and the hills, gradually assumes the dimensions of a river and finally debouches into the Mississippi, as do the St. Francis and the Yazoo. Mr. Harrod.

It is a part of the plan proposed by Mr. Brown, to build embankments on both sides of this main collecting and discharging conduit, thus cutting off all tributary drainage from its natural outfall, and making it necessary to lift over these embankments, by pumps, the run-off of 50 ins. of rainfall over 20 000 000 acres. In the consideration of this plan, the following quotation is made from Mr. Brown's discussion:

"Our country, to-day, * * * can, perchance, * * * raise the necessary funds to construct and maintain these very large and expensive levee lines" (that is, such as are now two-thirds completed on the river bank); "but in times of adversity, which every country may expect to experience, and funds are lacking to maintain them properly, what will become of this great levee system, which requires constant watching, guarding and the annual expenditure of large sums of money? And if the levee system, when constructed, * * * is by necessity forced to be neglected, what becomes of our rich alluvial country?

"Works affecting such enormous values, as do the works of protection against inundation by the floods of the Mississippi, must, of necessity, to be worthy of adoption, be such as will not confiscate the country in their construction; and also such as will serve reasonably well the purpose for which they were constructed, were they, from expediency, forced to be neglected for a time."

The discussion by Mr. Haupt presents no definite plan as an alternative for the completion of the levee system, but is critical in its attitude, and urges the co-operation of levees, reservoirs and outlets.

The advocates of outlets are careful to state that they do not mean mere gaps in the levees, through which the superabundant flood water may escape, but scientific openings controlled and regulated so as to discharge just water enough. They fail, however, to note that whatever the character of the outlet, or the volume discharged, it must be confined and conducted to the sea, however distant that may be, and not permitted to spread over adjacent territory. This can only be done by more levees, with the additional danger (which is proportionate to the length of line) and cost of construction, guarding and maintenance.

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The alluvial river is divided by many islands. These appear, disappear, and change form and position. A permanent adjustment between the discharge capacity of the main channel and the island chute is seldom, if ever, reached. One is constantly enlarging at the expense of the other. Many islands have joined the nearest shore by the filling of their chutes, while others have crossed the river, which has opened the chutes, by scour, to sufficient dimensions to accommodate the main discharge. The law under which these changes take place will be equally active in outlets. They will either enlarge to uncontrollable dimensions, or silt up and require frequent dredging to preserve their efficiency. Mr. Haupt quotes a description of the ideal channel existing through the 310 miles from Red River down to the Passes, and inferentially assigns this excellent condition to the presence of outlets. With no intention of claiming this as entirely the result of levees, but recognizing more remote hydraulic agencies, it should be stated that but one insignificant outlet exists, or has existed for 40 years, from Red River to the lower end of the levee system, about 275 miles, and to within a short distance of the head of the Passes; that this is now to be closed with a dam and lock because the completion and maintenance of the sub-levee system, by which its discharge is confined and conducted to the sea, is much more costly and difficult than the necessary enlargement of the river levees; and that along this reach of the Mississippi the levees have been built longer and maintained better than on any other part of the river. The "consistency of stage" in this section, attributed by Mr. Haupt to outlets, is really due to the proximity of the outfall, where slope ceases.

With reference to the claim that the opinion that outlets must occasion deposits in the channel falls to the ground after the careful investigations of the sections at certain crevasses, and an extensive series of measurements made with especial reference to testing this assumption, it must be observed that, to have any bearing on the question, such investigations and measurements must consist: First, of a sufficient number of cross-sections to cover some miles of river below the site where a crevasse is to occur, and the repetition of these sections after the crevasse has broken and run for a sufficient time; or, second, of a similar series of cross-sectioning below a crevasse which has run a sufficient time to cause deposit, and its repetition after closure and the passage of a flood of sufficient violence to remove any deposit which may have occurred.

No such examinations have been made, except by the Mississippi River Commission. It is recorded in the physics and hydraulics of the Mississippi River that certain cross-sections were sounded below two crevasses of 1849, and that these soundings were repeated in subsequent years, but the details of the work are not given, and it is not even stated whether, when the later soundings were made, the crevasses

had been closed, and a sufficient flood had passed to show the comparative effect on the channel of an overflowing and confined discharge. Without this information, such observations are of little or no value. On the other hand, the Mississippi River Commission has made surveys at Bonnet Carre, Morganza, at three of the crevasses of 1882, and has continued the comparative surveys of the United States Coast and Geodetic Survey at and below Cubits Gap. All these examinations indicate clearly the reduction of channel capacity as the result of the several outlets, or its enlargement, subsequent to the closure. Similar studies are now being made in connection with the crevasses of 1903. Mr. Harrod.

Tables Nos. 1 and 2, giving the comparison between certain elements of the river, width, area, and mean and maximum depths, in 1881, 1882 and 1883, and in 1894, 1895 and 1896, were presented in the writer's opening discussion as showing a tendency toward greater uniformity of depths and an increase of the discharge capacity of the channel in the thirteen years between these comparative surveys, during which period levee construction had been active. It was then said that:

"There is a limit to the value of the results obtainable even by this exhaustive process, * * * A comparison between the two surveys would be conclusive in proportion to the similarity of the stage conditions preceding them and prevailing while the parties were in the field."

A falling or low stage would have a tendency to scalp or channel the bars and fill the pools, while a rising or high stage would have the opposite effect. The enlargement of width and area at medium and bank-full stages is a permanent result when compared with the elevation and depression of the crests of bars, which vary from year to year from obscurer complicated causes. Crossings which are troublesome to navigators in some years disappear in following seasons as obstructions, to be replaced by others.

In the same part of the discussion other evidence was submitted against the assumption of any general elevation of the bed of the river. Nevertheless, these tables have been cited by Mr. Haupt as containing proof of such a movement. But both the uncertainty of the argument of the tables when applied to the bed of the river and of Mr. Haupt's deductions from them are shown by the fact that the low water of 1895—the year when the later surveys were made—reached a lower stage at every gauge station on the Mississippi, with one exception, from Cairo to Red River, than had ever been reached before by differences ranging from 0.35 to 1.80 ft. and averaging 1.1 ft. This statement is confined to Red River as a lower limit, because, with the great depth, and absence of bars from there down, the low-water flow line is a function of the volume and friction of the bed, while above Red River the surface is controlled by the elevation of the

Mr. Harrod. bars and crossings, and represents the changes they may be undergoing. This condition of low stage in 1895 appears to have been the result of the depression of the bed, rather than of the small discharge, since in no one of the tributaries, excepting the Wabash, and the Ohio below Louisville, were the lowest stages reached during that year.

Mr. Haupt's criticism of the present alignment of the levees is well taken, and will not be objected to by the engineers responsible for it, although the application is to the past practice of levee building, rather than to the theory of the confinement of floods to a single channel by levees. The illustration, however, is unfortunately chosen, as the widening about Mile 400 is the necessary gap between the lower end of the White River and the head of the Tensas Basin, through which the Arkansas and White Rivers discharge, and the levee causing the gorge 30 miles below has been abandoned for several years and retired two or three miles.

The present irregular alignment is only a phase in "the evolution of levees," and is the result of the paramount importance, in the past, for both theoretical and economic reasons, of establishing and maintaining the continuity of the line. When a gap occurred, the only practicable thing, with the means at hand, was to build the shortest possible loop around it. When a narrow and projecting point was reached, the levee was run across it. These imperfections of alignment have long been realized and accepted only as of necessity. It is with levees as with railroads. The first thing is to get there—to open up the country. When the financial development allows more than the maintenance of roadbed and rolling stock, the improvement of grade and alignment receives attention. The rapid influx of population and investment to the alluvial valley has made the extension of protection against such floods as recur with substantial regularity absolutely and immediately necessary, and this has strained the resources of the riparian communities, and the limit to which the Government has, as yet, seen fit to extend its appropriations. With the resources following success and prosperity, the makeshifts of an emergency will be rectified. Even now, the question of alignment is receiving attention, and, in some cases, spurs are built along the axes of points, equalizing the width of the river, and preventing the race of water across them.

Concerning the disposal by the main river of material derived from the tributaries and its own caving banks, it must be said that an amount nearly, if not quite, equal to that contributed by the caving banks is used in building out and up the opposite shores. This process has been going on ever since the valley was first known, and it has not been observed that it has been hastened by the building of levees. A gradual widening was shown by the earlier reconnaissances and surveys, and in the latest surveys, made within the period of ac-

tive levee building, and mentioned in the opening of this discussion, the increase of width is surprisingly small. There is now, and always will be, left, on both sides, along the greater part of the length of the stream, or above Red River, about 800 out of its 1 000 miles, a wide foreshore between the levees and the natural bank, for the deposit of material lifted by the stream in flood time. As this is not deeply submerged, and is generally obstructed by a dense growth, the velocity of the overflow is so reduced as to make the conditions favorable for the arrest of suspended sediment. Mr. Harrod.

There is another factor which, although not closely determinable in amount, is evidently of great importance in the disposal of the solid material brought in by the tributaries and transported by the river. The greater fineness of the sand, and the smaller size and quantity of the gravel at lower points in the river is very observable. From Cairo for some distance down there is a gravel bar at the head of most tow-heads and at the entrances of chutes, at points where the depth decreases and the velocity is checked. Passing down the river, the number and extent of these accumulations is reduced, as well as the size of the material of which they are composed. There is no important gravel bed found below Profit Island, 250 miles above the mouth of the river, and this is mainly, if not exclusively, contributed by Thompson's Creek, a small, but torrential tributary from the Mississippi hills. The attrition of particle with particle, on the way down, wears them away, and the result is as if they were dissolved. The fineness of the waste makes it transportable, even at slow velocities, for great distances. It floats from the Missouri for many miles out into the Gulf of Mexico, and has a share in giving the milkiness of color to the water of the lower river with which the settling basin and filter have so much difficulty in dealing. Yet its importance in disposing of solid material is realized from the fact that the loss of half its diameter by a grain of sand or a pebble means the loss of seven-eighths of its contents and weight. It is estimated by physical geographers that 1 400 000 000 cu. ft. of solid material are dissolved annually by rain and other agencies from the surface of the drainage basins, and carried down the main trunk of the Mississippi, in solution. This is not recognized in plans for the improvement of the river and its alluvial valley, and the same is true of the large, but impalpable, product of the attrition between particles of sand and gravel on their journey from the mountains to the sea.

The dream of using the sediment, carried in suspension by the river and escaping over its banks during overflow, for raising the valley lands, is so attractive that it occurs to everyone who has occasion to approach the study of the physics of the Mississippi Delta, and lasts until investigations show its utter impracticability for general application.

Mr. Harrod. The subject was investigated carefully by Humphreys and Abbot, accomplished students of the Mississippi River, and the ablest advocates of the theory of outlets. The conclusion of General Humphreys, concurred in by General Abbot, is, when applied to the St. Francis Basin, that if the water escaping into this basin during the great flood of 1858 had carried the average amount of sediment for flood stages, it would have sufficed to have filled the basin, if evenly distributed, one-twenty-fourth of an inch, and that the effect in this year was twice that of a year of average overflow. In general, he says:

"The figures exhibited show that such a process on a large scale is impracticable. The only practicable way of reclaiming the swamp lands is to levee the river banks securely, and, as cultivation extends inward, to establish a proper system of drainage."

The most accurate data obtainable concerning the physics of the river show that, as an engineering factor in the reclamation of the alluvial lands, it is absolutely trifling from its slowness and unequal distribution. The authorities, Humphreys, Abbot, Russell, Davis and others, concur in the estimate that the amount of sediment annually carried in suspension by the main trunk of the Mississippi corresponds to a rate of denudation of the surface of the drainage basin, from this source, of 1 ft. in about 5 376 years. As the area of the basin is about 1 250 000 sq. miles, and that of the land subject to overflow from the Mississippi, 30 000 sq. miles, or a ratio of about 42 to 1, the amount of material from the basin, if spread evenly over the alluvium, would raise it at the rate of 1 ft. in 128 years, or 1 in. in $10\frac{2}{3}$ years. But this preliminary assumption is subject to certain limitations. In the first place, high waters of magnitude enough to cause overflow over the natural banks do not occur annually, and great floods are infrequent. Secondly, the period during which overflow lasts, even in floods of magnitude, does not usually last more than two months. Thirdly, the mean quantity escaping during this period cannot be estimated as exceeding one-third of the entire flood discharge of the river. It is submitted, therefore, that an escape of one-third of the flood volume during one-sixth of every year, is a large estimate of the force available for the distribution of sediment over the alluvial lands, and that, therefore, the rate of fill over these lands, if evenly distributed, could not exeed 1 in. in 192 years. Of course, the distribution of sediment would not be uniform, for by far the greater part would be arrested near the bank, while it is highly improbable that the lowest lands, remote from the river, and needing elevation most, would be raised at a rate exceeding 1 in. in 500 years.

The terms of this problem are so immense and variable that they only admit of its approximate solution, but it is believed that enough has been said to show that, however well it might have been to defer the settlement of the valley for a term of centuries, but little aid can now be expected in its general improvement by sedimentation. The

time for this, if it ever existed, has gone by, and the vested interests are too great and active to admit of interruption by any such slow process. Mr. Harrod.

The Mississippi is a sedimentary stream, flowing through an alluvium of its own formation, in a bed adjusted to its needs by its own forces. Although geologically young among rivers, it is mature in the sense of having established a permanent regimen, under which its slope, velocity, length and section are in substantial adjustment with its discharge and the stability of the material through which it flows. It builds up its banks on one side as fast as it tears them down on the other, and strives to maintain its present length.

The phenomena characteristic of this type of river are clearly exhibited throughout its course. With each increment of volume from an affluent, its slope is flattened without loss of mean velocity. Thus, above the junction of the Ohio, it is 0.5 ft. per mile ; from the Ohio to the St. Francis it is 0.424 ft.; from the St. Francis to the White 0.344 ft.; from the White to the Yazoo 0.317 ft; from the Yazoo to the Red 0.265 ft.; from the Red to the Head of the Passes 0.180 ft., and, then, when this combined discharge is subdivided between the several Passes to the Gulf, the slope is again increased to about 0.3 ft. per mile. Throughout this course, in which the slope is steadily decreased as the volume is increased, discharge observations show that substantially the same mean flood velocity prevails, from Cairo to the Gulf, and, therefore, the finer material found in suspension or rolled along the bottom is, toward the lower end, more readily transported.

Wherever, in its course, the flood discharge of the river is decreased, a contraction of waterway by deposit has been observed. This statement applies both to the long reaches along the fronts of basins, where, during unleveed ages, one-third of the discharge of great floods has escaped over the banks, to be collected and returned to the river by the natural drainage system, and also to the outlet through crevasses of magnitude, discharging 200 000, 300 000, and even 400 000 cu. ft. per second.

Surveys, having for their direct object the ascertainment of any changes in the bed of the stream affecting its channel capacity, as the result of natural causes or as the result of levee building, have disclosed a general movement toward uniformity in depth and an increase of channel capacity. These observations were not confined to a single gauge station or cross-section, but were continued for fifteen years over hundreds of miles of river and thousands of cross-sections.

That part of the subject relating to the elevation of the river bed has been discussed with learning and authority by General C. B. Comstock, M. Am. Soc. C. E., with the following conclusion*:

"The opinion so often held that levees cause a river-bed to rise is probably due to the fact that the bed of a river does sometimes rise although

* Appendix A to the Report of the Mississippi River Commission for 1890.

Mr. Harrod.

leveed, and hence it is concluded that the levees cause the rise. Any sedimentary stream, having a definite succession of stages and discharges and flowing in its own alluvion, finally takes such a slope as will give a velocity sufficient to enable it to carry its sediment, whether derived from above or from its own banks and bed, farther down-stream, without, on the whole, scouring or filling its bed. An average velocity less than this will give rise to deposits in its bed, or if it is crooked it will become straight, thus in either case increasing its slope and velocity towards their normal values. An average velocity greater than this will scour its bed, or cause caving in its concave bends, thus increasing its length and diminishing its slope and velocity to such values as its bed can bear without on the whole scouring or filling. When therefore the slope of a sedimentary stream suddenly diminishes from that which it needs for a stable regimen its velocity also diminishes; it drops part of its alluvion, and its bed rises. Thus, when the Mississippi enters the Gulf of Mexico, its slope suddenly diminishes; its velocity diminishes, and it builds up bars out in deep water. So the Adige, when it reaches the low plains of the Po, needs for permanence a steeper slope than the country has, and raises its bed above it. In all these cases the bed would rise without levees."

"There is one more cause for the rise of bed of a sedimentary river, which, however, acts at a very slow rate. The Mississippi pushes its mouths out into the Gulf at the rate of about 4 miles in a century, and this increase in length requires a corresponding increase in fall of water surface to make the waters flow out. An increase of 4 miles in length would, with existing slopes, raise the high-water surface at New Orleans about 0.7 ft. The cost of raising levees to correspond with this rise in the water surface would, as has already been stated, be a small part of the annual cost of the system."

That the confinement of floods between levees would have the immediate effect of increasing flood heights was, of course, anticipated. But it can be said, even on the assumption of a permanent or inerosible bed, that this increase of height will only be in proportion to the increase of discharge, and that to this there is a limit. There have been facts given in the opening of this discussion which lead to the conclusion that this limit, as far as the discharge of the affluents is concerned, has been nearly, if not quite, reached, and that there only remains the improbable contingency of a more synchronous combination of tributary discharges than has ever yet been known. But the bed is not inerosible, and there are reasons given in the preliminary discussion why the forces of a uniform and combined flood volume will, in time, remove the accumulation of sediment left in the bed by high waters depleted along the basin fronts through ages of overflow, and thus abate the increased flood heights now experienced as the immediate result of levee building.

Reservoirs and outlets, like levees, must be judged both by their conformity to hydraulic theory and by their practicability. Withholding the excessive part of the flood discharge of the tributary by reservoirs is distinctly an aid in abating flood heights in the lower river, and thus in the reclaiming of its low lands from inundation, and

the same means serve for irrigation where most needed. Thus the irrigation of the arid lands and the leveeing of the alluvial lands are closely connected as co-operative projects. Unfortunately, the practicable extension of the reservoir system is very limited. It finds no application on the Ohio, and very little, as a factor in reducing floods on the lower river, on the Upper Mississippi. Mr. Harrod

Below Cairo it is quite impracticable. The only basin which has been proposed as a reservoir site—the St. Francis—comprises 6 000 sq. miles of land of great fertility and increasing value, the homes and improved properties of a large population, and hundreds of miles of railroads, not to mention two Congressional Districts. Besides the acquisition of the necessary rights, the works for impounding and controlling the surplus flood waters would be very extensive and costly, requiring skillful and probably dangerous maintenance and operation. Theoretical questions concerning the permanence of channel capacity and of continued flood relief with a reduced discharge also arise as objections to such a project. At this late period, when the basin is so largely occupied and advancing in wealth so rapidly, and when the levee system for its protection is so far advanced, the proposition does not present either economic or engineering advantages. The present and prospective value of the site for farming and industrial purposes is enormous, and its protection from overflow by levees can be accomplished more cheaply, more safely and at an earlier time, than by any other method.

The theoretical objections to outlets are well stated* by General Comstock as follows:

"A sedimentary river flowing in its own alluvion only acquires a stable regimen when it has taken a slope suitable to its varying discharges and to the material through which it flows; and, as a rule, these slopes diminish as the size of the river increases, and increase as the size of the river decreases."

* * * * * * * *

"These examples are sufficient to illustrate the general rule already stated, that sedimentary rivers flowing in their own alluvion take larger slopes the smaller they are. Hence, if at Lake Borgne or elsewhere in its Delta, the Mississippi were divided into two rivers, since each would be smaller than the present river, the two new rivers would go to work to obtain the new and steeper slopes suited to dimensions smaller than those of the original river, and hence would build up their beds. This process would only cease when the steeper slopes needed by each were obtained. Since both rivers would then have one end at the gulf, and have steeper slopes up to their point of divergence than the main river now has, the flood surface of the river at that point would be higher than now."

* * * * * * * *

"It may be concluded that the reduction, by any large amount, of the flow of the Mississippi at Lake Borgne will be ultimately followed

* Appendix B, Report of the Mississippi River Commission for 1890.

Mr. Harrod. by a rise in the flood heights at that place and a shoaling of the river below and at its mouth."

* * * * * * * *

"Both theory and experience show that when, at all stages, a reduction in the size of a river flowing in alluvial soil is made, or the river is split in two, the smaller rivers gradually take greater slopes than the main river had. Hence both the main river and the new river would gradually increase their slopes to suit the new conditions. Since the slope begins at the Gulf, it can not become greater on the main river below Lake Borgne, which is now nearly straight, without increasing flood heights at Lake Borgne. After some years, then, if both routes to the sea remained large rivers, the flood level above the outlet would be higher than it is now, unless, as indeed is not improbable, the large amount of sediment which would be dropped into Lake Borgne (where the flood velocities would at first be but about one-sixth of those in the Mississippi) should close this outlet, thus repairing the injury done to the main river. A large diversion of flow from the Mississippi to Lake Borgne would also seriously diminish the depths at the present mouths of the river."

When to these objections are added the practical difficulties and costs of controlling the discharge of an outlet with additional levees and regulation works, the conclusion is inevitable that the reclamation of the alluvial valley from overflow can be accomplished most cheaply, safely and speedily by the completion of the levee system to sufficient grades and dimensions.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

FREDERICK WINN BOND, M. Am. Soc. C. E.*

DIED JULY 12TH, 1903.

Frederick Winn Bond was born of New England parentage in Dover, New Hampshire, on April 14th, 1852. The family moving to Waltham, Massachusetts, shortly after, his early education was obtained in the public schools of that place. He attended college at Yellow Springs, Ohio.

Mr. Bond began his engineering career in 1870 as a rodman on the St. Louis, Council Bluffs and Omaha Railroad, now a part of the Wabash System. He was afterward employed as a draftsman in the City Engineer's office at Omaha, Nebraska. In the year 1872 he was employed as a rodman and levelman on the Union and Southern Pacific Railways. From there, in 1873, he went to the City Engineer's office at Toledo, Ohio, but during the same year returned to Omaha and was employed as an Assistant Engineer in the United States Engineer Department at that place. During this period he was connected with the "Hayden Geological Survey," of the Territories, operating in the then little known Yellowstone country, an experience which he often spoke of in later life as very interesting.

In 1876 he was engaged as mechanical engineer in a Chemical and Blast Furnace Works at Bangor, Michigan, where he remained until 1879, at which time he became an Assistant Engineer on the St. Louis and San Francisco Railway, under James Dunn, M. Am. Soc. C. E., then Chief Engineer of that railway, with general headquarters at St. Louis, Missouri. He remained with this company until the year 1889, during which time, in the years 1887 and 1888, he made extensive surveys through the Indian Territory and Texas Panhandle for the location of the Middle Division of the Atlantic and Pacific Railroad, then jointly owned by the Atchison and San Francisco interests. Leaving the St. Louis and San Francisco Railway in 1889, he became Chief Engineer of the Kansas City, Nevada and Fort Smith Railroad, now a part of the Kansas City Southern System. He remained there until 1891 when he accepted the position of Chief Engineer of the Kansas and Texas Coal Company of St. Louis, which position he held until 1897. During parts of 1897 and 1898 he was engaged in special work, for the Engineer Department of the Atchison, Topeka and

*Memoir prepared by R. L. Van Sant, M. Am. Soc. C. E.

Santa Fé Railroad Company, in Texas. Early in 1898 he became Principal Assistant Engineer of the St. Louis and Oklahoma City Railroad, now a part of the St. Louis and San Francisco System. In 1899 he was appointed Chief Engineer of the "Frisco" Railroad, operating department. In 1900 he resigned that position to become Chief Engineer of the Fort Smith and Western Railroad, which position he held at the time of his death.

The existence of the latter corporation is due primarily to Mr. Bond's foresight and business enterprise in locating and securing leases on valuable coal properties in the Indian Territory; these concessions, later, being transferred to the present railroad corporation. Much of Mr. Bond's time for the past eight years was given to this enterprise, and actual construction was finally begun some two years ago under his supervision as Chief Engineer.

While connected with the Kansas and Texas Coal Company, Mr. Bond made many innovations and improvements in coal mining and hoisting machinery, some of which were patented by him and are now in general use.

The writer's acquaintance with the deceased began at the time he came to the "Frisco" Railroad in 1879, being associated together in the location and construction of important extensions of that road during the stirring days of the early eighties. The deceased's acquaintance and railroad experience during this period extended over Southern Missouri, Northern Arkansas and the Indian Territory, in connection with the above-named extensions. He made friends with all, and left pleasurable reminders of his strong personality, genial disposition, bright wit, and, occasionally, sharp sarcasm, wherever he "pitched his tent." He was genial and generous with his friends, but his wit was often very pointed when dealing with those who opposed him. There was scarcely a man on the "Frisco" Railroad, from the Road Department to the General Office, who did not know and admire "Fred Bond." All, from the lowest to the highest, express genuine regret at his untimely death, and extend sympathy to the bereaved family.

Mr. Bond belonged to that practical and resourceful class of engineers who got their experience during the last quarter of the past century under conditions calculated to develop a high order of resourcefulness and self-reliance, together with a promptness to act and assume responsibility, that is hardly possible under present conditions of organization and methods of practice. Being possessed of an eminently practical turn, yet he had much of the artistic instinct, and felt and appreciated all the better impulses of human nature. "Fred Bond" was a most delightful companion, a good comrade and a stanch friend, as well as an engineer of high professional qualifications.

Mr. Bond was married to Miss Elizabeth Loup, in June, 1875, at

Belvedere, Illinois, and she and four children survive him. He died at Fort Smith, Arkansas, on July 12th, 1903, and was buried in the family lot, at Kirkwood, St. Louis County, Missouri.

He was elected a Member of the American Society of Civil Engineers on December 7th, 1898.

MARTINIUS STIXRUD, M. Am. Soc. C. E.*

DIED DECEMBER 28TH, 1901.

Martinius Stixrud was born in Thoten, Southeastern Norway, on January 28th, 1857. He was graduated from Chalmers Technical Institute, at Gothenburg, Sweden, in 1878, and continued the study of Civil Engineering at the Polytechnicum, at Aachen, Germany, during the next year. In the spring of 1881 he came to the United States.

His first summer in this country was spent as a transitman and draftsman on the Manitoba Railways. During the winter of 1881-82 he was engaged as draftsman and computer in the Bridge Department of the Chicago, Milwaukee and St. Paul Railway, at Minneapolis. Early in 1883 he was engaged by the Northern Pacific Railroad, with office at Brainard, but from there was sent out to the Pacific Coast by that company.

In 1883 he designed the switch-back over the Stampede Pass, under V. G. Bogue, M. Am. Soc. C. E., who at the time was Principal Assistant Chief Engineer of the road. Mr. Stixrud continued his engagement with this railroad until 1885, and during part of this time he was Assistant Engineer to W. H. Kennedy, M. Am. Soc. C. E. In 1885-86 he was Engineer on the location and construction of the Oregon Pacific Railroad. During 1886-87 he was Locating Engineer for the Seattle, Lake Shore and Eastern Railway, running lines across the Cascade Mountains through the Snoqualmie Pass. This party suffered a great deal during the winter, from exposure and shortage of provisions, and at that time Mr. Stixrud contracted an ear trouble which caused him much pain ever afterward.

In 1887-88 he was Engineer in Charge of Location and Construction of the Seattle, West Coast Railway (afterward the Seattle, Lake Shore and Eastern Railway). In 1888 he went to Spokane, in the interests

*Memoir prepared by S. T. M. B. Kielland, M. Am. Soc. C. E.

of the same company, and designed and constructed the bridges, of this company, over the Spokane River. In 1889 he continued as Locating Engineer for the same company. In short, up to this time he had been engaged constantly on railroad work, on both location and construction, and his reputation as a reliable and able engineer in those branches was established.

In 1890, very much against his inclination, Mr. Stixrud became City Engineer of Seattle, but did not give satisfaction to the politicians, who were unable to use him and his office as they pleased. He was most shamefully treated, and although ousted from office, was completely exonerated, and came through this blackmailing process victorious. Some time before this, he was engaged with J. E. Ericson, M. Am. Soc. C. E., later City Engineer of Chicago, in preparing plans for water and sewerage systems for Seattle, under Mr. Benezette Williams.

From 1890 Mr. Stixrud was located permanently in Seattle, and practiced as a Consulting Engineer, forming a partnership in 1892 with Mr. C. Näsiten. To be a consulting engineer in that western country required the most diverse knowledge and practice, thus bridge and structural engineering, water supply, sewerage, drainage, irrigation. and also railroad surveys, comprised the firm's work.

In 1892-93 Mr. Stixrud spent the winter in California and Mexico, having in view the irrigation of the desert lands in the Colorado River Basin. Plans were prepared to irrigate 600 000 acres. The proposed intake was on the Colorado River near Hanlon's Ferry, not far from Yuma. However, the business part of the undertaking failed at that time. In 1893 he was engaged as Engineer for the Board of Tideland Appraisers for King County, Washington. In this capacity he made a very extensive survey of Seattle and Ballard Harbors, establishing harbor lines and waterways, and plotted the tideland areas at Seattle, Ballard and part of Tacoma Harbors. Especially for Seattle, this was a work of great importance, as it dealt with the future plans of Seattle Harbor, railway terminals and manufacturing districts. Mr. Stixrud did not succeed in getting his general plan of the main part of Seattle Harbor accepted. Captain T. W. Symons, M. Am. Soc. C. E., representing strong interests, had a revised plan, which was accepted. Mr. Stixrud's plan was one with tidal basins, the rise of the tide being 16 ft. Captain Symons' plan was for open waterways, which appeared to suit the immediate or near future. Mr. Stixrud had ignored the South Canal Waterway.

In the winter of 1896-97 Mr. Stixrud was the Chief Engineer for one of the cable tramways, constructed over the Chilkoot Pass, Alaska.

Mr. Stixrud died in Seattle, after an illness of seven weeks, the cause of death being congestion of the brain, considered to have been

caused primarily by his exposures in the Snoqualmie Pass in the winter of 1886–87.

The foregoing gives a general outline of Mr. Stixrud's professional work. As to his character, too much cannot be said. He was of a cheerful, pleasant disposition; admired and respected by all, and was an excellent representative of the Scandinavian race—honest, true and brave. In appearance he was tall, erect and fair. He left no fortune, but many friends. He was not married.

Mr. Stixrud had many qualities through which he was especially adapted to his profession; he was of an inventive mind and had great designing abilities, mechanical devices being his hobby. Where he made his home he was an engineer of high standing, but, without doubt, he would have attained more prominence if he had been favored by a location in which his pure engineering qualities would have been appreciated more than could have been the case in the new and undeveloped West. F. W. D. Holbrook, M. Am. Soc. C. E., under whom Mr. Stixrud served as an assistant during the construction of the Seattle, Lake Shore and Eastern Railway, in 1888-90, writes as follows:

"Mr. Stixrud was a young man of fine physique and presence, and had been well educated in foreign technical schools. He was very companionable, and of sterling integrity. I mention this last, as after having taken the office at one time as City Engineer of Seattle, when his political opponents trumped up some charge against him that led to his resignation, but no one knowing the facts ever laid anything to his discredit on that account."

W. H. Kennedy, M. Am. Soc. C. E., Chief Engineer of the Oregon Railroad and Navigation Company, and under whom Mr. Stixrud worked for several years, on the location and construction of the Northern Pacific Railroad, writes:

"Shortly after Mr. Stixrud's arrival in this country, he was engaged with me, on the location of the Green River Division of the Northern Pacific Railroad, as topographer. I can only say, that he was one of the finest topographical engineers I have ever known, and a location based on his topography rarely required to be amended after being once run in on the ground. I knew him intimately from that time until his death, and had no friend whom I esteemed more highly. His loss at such an early age was a loss to the profession, of which he was an honored member. I had always looked forward to a brilliant career for him, as he had marked ability as a designer and has left many monuments of his skill as such in Seattle, Washington, where, at the time of his death, he was in the active practice of his profession."

The foregoing will give some idea of the life and character of Martinius Stixrud, but the ennobling effect of his company, the kind but manly and strong appearance of the man, his excellent manners, and his sincere friendship toward those who had the privilege of being near him, can only be appreciated fully by those who came in contact with him. He was sincere and sober in business, but in conversation

and discussion he was bright and entertaining. Mr. Stixrud was one of the most enthusiastic yachtsmen of Seattle, and his boat was for a long time the champion of her class.

Thus his life was vigorous, strenuous and manly. His noble example as a man and engineer will have a lasting and elevating effect on all who knew him.

Mr. Stixrud was elected a Member of the American Society of Civil Engineers on April 3d, 1889.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

November 4th, 1903.—The meeting was called to order at 8.40 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 92 members and 16 guests.

The minutes of the meetings of October 7th and 21st, 1903, were approved as printed in *Proceedings* for October, 1903.

A paper, by Eugen Goetze, Esq., entitled "Filtration for Public Water Supplies, with Especial Reference to the Double Filtration Plant at Bremen, Germany," was presented by Rudolph Hering, M. Am. Soc. C. E. A communication on the subject from W. Kiersted, M. Am. Soc. C. E., was presented by the Secretary, and the paper was discussed verbally by Messrs. H. W. Underwood and Morris Knowles,

who illustrated their remarks with lantern slides. Messrs. Allen Hazen, J. P. A. Maignen, George W. Fuller, William B. Fuller, John H. Gregory, George A. Soper and Thomas H. Wiggin also spoke on the subject.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Burr Bassell, Kernville, Cal.
Kort Berle, Washington, D. C.
John Howard Clark, Malden, Mass.
Walter Edward Dauchy, Chicago, Ill.
John Rose Wilson Davis, Jersey City, N. J.
Charles Young Dixon, Amherstburg, Ont., Canada.
Howard Carleton Holmes, San Francisco, Cal.
Frank Gilbert Jonah, Alice, Tex.
Arthur Louis Phillips, Memphis, Tenn.
Ysidoro Ygnacio Polledo, Matanzas, Cuba.

As Associate Members.

Walter Hinds Allen, Brooklyn, N. Y.
Elmore David Cummings, Chicago, Ill.
Erastus Roland Simpson, Boston, Mass,
Frank Edward Winsor, New York City.

The Secretary announced the election of the following candidates by the Board of Direction, on November 3d, 1903:

As Associates.

William Clarence Olds, Erie, Pa.
Herbert Sedgwick Wilgus, Brooklyn, N. Y.

As Juniors.

Barnett Braslow, New York City.
Edward Merriam Chadbourne, San Francisco, Cal.
John Williams Doty, New York City.
Joseph Thomas Lillich, St. Louis, Mo.

The Secretary announced the death of Robert Henry Thurston, elected Member December 6th, 1871; died October 26th, 1903.

Adjourned.

November 18th, 1903.—The meeting was called to order at 8.40 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 102 members and 10 guests.

A paper, entitled "Dock Improvements at Liverpool," by George Cecil Kenyon, Assoc. M. Am. Soc. C. E., was presented by the Secretary.

The subject was discussed by the President.

The Secretary announced the death of NORMAN SMITH LATHAM, elected Junior July 3d, 1889; died November 10th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

November 3d, 1903.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Craven, Croes, Jackson, Osgood, Pegram, Schneider, Swain and Wilgus.

A report was received from the Committee of Conference on the proposed Joint Engineering Building, and action was taken authorizing a statement of the matter, as it stands, to be issued to the membership sixty days before the Annual Meeting.

The proposition for the appointment of a Special Committee on Concrete and Steel-Concrete was considered, and a Committee of the Board appointed to prepare its recommendations for presentation to the Annual Meeting, together with a statement of the arguments for and against the appointment of such Committee.

Reconsideration Ballots were canvassed in accordance with the Constitution.

Applications were considered and other routine business transacted.

Two candidates for admission as Associate, and four as Junior, were elected.*

Adjourned.

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* See page 408.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, December 2d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "A Desirable Method of Dredging Channels through River Bars," by S. Maximoff, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for October, 1903.

Wednesday, December 16th, 1903.—8.30 P. M.—At this meeting, a paper, by Emile Low, M. Am. Soc. C. E., entitled "The Breakwater at Buffalo, N. Y.," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL MEETING.

The Fifty-first Annual Meeting will be held at the Society House, January 20th and 21st, 1904. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The annual reports will be read, officers for the ensuing year elected, members of the Nominating Committee appointed, and other business transacted.

The arrangements for excursions and entertainments will be announced later.

NOMINATING COMMITTEE.

The Constitution provides that at the Annual Meeting of each year, seven Corporate Members, not officers of the Society, one from each of the geographical districts into which the Society is divided for this purpose, shall be appointed by the meeting to serve for two years.

The usual blank request for suggestions as to representatives of each district, for presentation to the meeting, will soon be mailed to Corporate Members.

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

As the details of the arrangements are developed, they will be announced in *Proceedings*.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an Engineering Exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

ROBERT MOORE, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
EDWARD C. CARTER, M. Am. Soc. C. E., Chicago, Ill.
MORDECAI T. ENDICOTT, M. Am. Soc. C. E., Washington, D. C.
JAMES L. FRAZIER, " " Frankfort, Ind.
WILLIAM JACKSON, " " Boston, Mass.
EMIL KUICHLING, " " New York, N. Y.
JOHN F. WALLACE, " " Chicago, Ill.
H. J. PFEIFER, Assoc. M. Am. Soc. C. E., St. Louis, Mo., *Secretary.*

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ACCESSIONS TO THE LIBRARY.

From October 14th to November 10th, 1903.

DONATIONS.*

GRAPHIC STATICS, WITH APPLICATIONS TO TRUSSES, BEAMS AND ARCHES.

By Jerome Sondericker. Cloth, 9 x 6 ins., 8 + 137 pp., illus. New York, John Wiley & Sons, 1903. $2.00.

This book is the outgrowth of an experience in teaching graphic statics at the Massachusetts Institute of Technology. While it deals specifically with problems encountered in building construction, it is intended to be serviceable to engineers and engineering students generally. As preparation, the author states that the reader should have a knowledge of statics and strength of materials, including beam stresses and deflections, as these subjects are commonly presented. An attempt has been made, in Chapter II, to develop a general method of dealing with frames where bending stresses occur in addition to tension and compression stresses. The Contents are: Introduction; Funicular Polygon; Forces in Equilibrium; Graphical Determination of Moments; Some Special Constructions for Funicular Polygons; Construction of Roofs, Loads, etc.; Determination of Reactions of Supports; Determination of Stresses; Counterbracing and Double Systems of Bracing; Three-Hinged Arch; Bending Stresses, Sway Bracing; Shearing Force and Bending Moment of Beams; Deflection of Beams; General Conditions of Stability of Masonry Arches, Abutments, etc.; Masonry Arch, Line of Pressure; Abutments, Piers, etc.

WATER POWER.

An Outline of the Development and Application of the Energy of Flowing Water. By Joseph P. Frizell, M. Am. Soc. C. E. Third Edition, Enlarged. Cloth, 9 x 6 ins., 6 + 646 pp., illus. New York, John Wiley & Sons, 1903. $5.00. (Donated by the Author.)

In this edition some typographical and numerical errors which had crept into former editions have been eliminated. The subject of dams on soft bottom has been extended, and a section added on dams in tidal waters. The length of wasteways in relation to the appurtenant drainage area has been more fully considered. The subject of tidal power has been outlined, and extended attention has been given to storage reservoirs. The subject of leases and rentals of water-power and land appurtenant thereto has also been more fully elaborated. The Contents are: Natural Watercourses; Dams for Water-Power; Construction of Dams; Dams of Masonry; Appendages of Dams; Movable Dams; Storage-Reservoirs and Reservoir Dams; Rock-Fill Dams; Reservoir Dams of Masonry; Examples of High Dams; Failures of High Dams; Canals, Gates, etc.; Hydraulic Motors; Water-Wheels; Turbines; Appendages and Attachments of Turbines; Canals; Development of Natural Water-Powers; Transmission of Power; Shafting and Wire Rope; Hydraulic Transmission; Transmission by Compressed Air; Transmission by Electric Current; The Power-House; Measurement of Water; Storage and Pondage of Water; Damages to Mill-Owners Resulting from the Diversion of Water; Leases and Rentals of Water-Power; Testing Water-Wheels. There is an index of six pages.

PRINCIPLES OF AMERICAN FORESTRY.

By Samuel B. Green. Cloth, 7 x 5 ins., 13 + 334 pp., illus. New York, John Wiley & Sons, 1903. $1.50.

The author states that this is a book on elementary forestry, and has been prepared especially for students and others beginning this subject. It is also intended for the general reader who wishes to secure a general idea of the subject of forestry in North America. Much of the matter included herein was originally published by the Geological and Natural History Survey of Minnesota under the title "Forestry in Minnesota." In this volume the matter is treated in a more general way and has been enlarged upon the better to adapt it to the whole country. The chapter headings are: The Tree; Tree Growth; The Forest; Forest Influences; Tree Planting on Prairies; Forest Regeneration; Propagation; Nursery Practice; Forest Protection; Rate of Increase in Timber Trees; Forest Mensuration; Forest Problems; The Uses of Wood; Durability of Wood; Forest Economics; Tabular Classification, Sylvicultural Data, and Uses of Important American Timber Trees; Glossary of Technical Terms Used in Forestry; A List of the Best Books on Forestry; Publications of the Bureau of Forestry and Other U. S. Departments of Special Interest to Students. There is an index of twelve pages.

* Unless otherwise specified, books in this list have been donated by the publishers.

NOTES ON ELECTRIC RAILWAY ECONOMICS AND PRELIMINARY ENGINEERING.

By W. C. Gotshall, M. Am. Soc. C. E., M. Am. Inst. E. E. Cloth, 9 x 6 ins., 5 + 251 pp., illus. New York, McGraw Publishing Company, 1903. $2.00.

This book is based upon a series of lectures delivered at Lehigh University, the subject of which dealt with the economics of the preliminary determinations and of the construction and operation of high-speed interurban electric railroads. The author has filled out the lecture notes, in some places adding matter thereto, and has arranged the subjects so as to follow the order in which they would be taken up in the investigation and construction of an electric railway undertaking of the type considered. With a few exceptions all the full-size original drawings and diagrams used in the lectures have been reproduced in this volume. Part of the book is devoted to a statement of the principles which should be followed in locating a proposed route so as to derive the maximum benefit from the territory to be served. The book is not designed as a treatise or exhaustive treatment of the subject as a whole, or of the details as indicated in the chapter headings. It is intended to "point the way," and embody some of the results of twelve years of practice and application. The Contents are: Introductory; Preliminary Office Determinations; Preliminary Field Survey; Detailed Office Investigation of Track Location; Preliminary Determination of Schedules and Equipment; Estimate of Earnings; Estimate of Probable Operating Expenses; The Final Survey; Track Construction; Overhead or Third-Rail Construction; The Power Station; Storage Batteries; Rolling Stock and Motors; Securing Rights of Way; Preparation of the Specifications; The Construction Period; The Organization of the Operating Department; Economic Considerations; Appendix. There is an index of three pages.

L. VICAT, SA VIE ET SES TRAVAUX.

Avec des Notes par Merceron-Vicat. Paper, 9 x 5 ins., 243 pp. Paris, Veuve Ch. Dunod, 1903. 3 francs, 50 centimes.

In this book M. Merceron-Vicat has recalled opportunely, at a time when the cement industry has become of considerable importance, the works of the creator of this new industry. The technical details are still of present-day interest and may be found useful by engineers and builders who are interested in hydraulic limes and cements. There is a short biographical notice followed by extracts showing L. Vicat's principal discoveries. The Contents are: Notice biographie; Chaux hydrauliques artificielles; Classification des chaux hydrauliques; Chaux-limites et incuits; Pouzzolanes artificielles; Ciments éventés et surcuits; Action de l'eau de mer; Délibération du Conseil municipal de Paris; Rapport d'Arago; Rapport de Thénard; Rapport de J. B. Dumas.

A MANUAL OF LAND SURVEYING.

Comprising an Elementary Course of Practice with Instruments and a Treatise upon the Survey of Public and Private Lands, Prepared for Use of Schools and Surveyors. By F. Hodgman. Morocco, 7 x 4 ins., 11 + 394 + 6 + 106 pp., illus. Climax, Michigan, F. Hodgman, 1903. $3.00.

This book contains the mathematical and instrumental matter usually found in text-books as well as a large amount of practical matter. It gives the United States laws relating to surveys and the latest United States Instructions to Deputy Surveyors. It tells how to subdivide sections of the United States Surveys and how to find lost corners and restore them when obliterated or destroyed. It also tells how descriptions in deeds are to be constructed and how to write correct descriptions. There are legal decisions and citations of more than two hundred cases from the highest courts in the United States, covering every point in the surveyor's practice which has been settled by them. In preparing this part of the work, every decision of the Supreme Court of the United States and of the Supreme Courts of the several States, which had a bearing on the surveyor's work, was consulted. The Contents are: Definitions; Instruments; Measurement of Angles; Passing Obstacles and Measuring Inaccessable Distances; Platting and Computing Areas; Curvelinear Surveying; Original Surveys; Subdivision of Sections; Resurveys; Relocating Lost Corners; Miscellaneous; Tables.

THE STAR IMPROVED STEAM ENGINE INDICATOR.

By Geo. H. Barrus, M. Am. Soc. M. E. Cloth, 7½ x 5 ins., 140 pp., illus. Boston, Star Brass Mfg. Co. $1.00.

The preface states that although in a sense an advertisement of the new indicator, this book is intended to be an unbiased statement of all the facts needed by a purchaser of this indicator, whether unfamiliar with the particular form of instrument described, or with the general subject. It is intended also as a useful book of reference and instruction in the practical work of indicating. Most of the diagrams here reproduced were taken for the purpose of this treatise, using one of the new type of instruments,

and nearly all were taken by the author. The Contents are: Introduction; Description of the Star Improved Indicator; Testing Springs; Care of the Star Improved Indicator; Diagrams Taken from the Star Improved Indicator; How to Indicate an Engine; How to Take a Diagram; Designation of the Various Lines of the Diagram; Use of the Indicator for Setting Valves; Working up Diagrams, Use of the Planimeter, etc.; Computation of Horse-Power; Steam Accounted for by Indicator Diagram; Cylinder Condensation and Leakage; Combining Diagrams; Steam-Pipe Diagrams; Leakage-Tests of Valves and Pistons; Tables.

CURVES OF CIVIL ENGINEERING.

The Transitman's Pocket Companion. Containing Instructions for Surveys to Locate the Center Line of Engineering Works, and Tables that are Needed in the Field, in Connection with Circular, Transition and Vertical Curves. By Arthur M. Haynes. Leather, 7 x 4 ins., 117 pp., illus. 1903. $2.50. (Donated by the Author.)

The author states in the preface that the excuse for this book is to advocate *arc* measurements. A new table of 1° curve functions is given, in accordance with a new definition for "degree of curve," found in the first paragraph of the text. Logarithms and tables of natural functions are not given because the author thinks they should not be used in the field. Special problems, too, are considered as belonging in the class-room. The subject of transition curves is made a prominent feature. A section on vertical curves is added, so that the ground may be better covered. While this subject applies especially to railroads it should also be applied to city street grades much more than it is. The Contents are: Circular Curves; Alignments of Engineering Works; Linear Measurements; General Discipline; Angular Measurements; True Meridian; Field Work; Transition Curves; Platting; Turnout Curves; Vertical Curves; Tables and Diagrams.

AMERICAN RAILWAY TRANSPORTATION.

By Emory R. Johnson. Cloth, 8 x 5 ins., 16 + 434 pp., illus. New York, D. Appleton and Company, 1903. $1.50.

This volume, as is stated in the introductory chapter, is concerned with the transportation service performed by steam or trunk-line railroads. It does not discuss the engineering and other technical questions of railroad construction and operation, but describes the American railroad system, gives an account of the service performed by the different branches of the railroad organization, considers the business relations of the railroads and the public, and discusses the problems of government regulation. The book is intended as a study in railway economics and as an introduction to the general subject of railroad transportation. The chapter headings are: Introduction—Definition and Scope of Transportation; Origin of the American Railway; Growth of the American Railway Net; The Mechanism of the Railway; The Present Railway System of the United States; The Railway Corporation and its Charter; Railway Capital; Earnings, Expenses, and Dividends; The Freight Service; The Passenger Service; The Express Service of the Railways; The Mail Service of the Railways; The Organization of the Service; The Accounts and Statistics of the Railway Service; Railway Competition and Agreements to Maintain Rates; Pools and Traffic Associations; The Present Situation; Monopoly and Competition in the Railway Service; Theory of Rates and Fares; Rate-Making in Practice; Railway Charges in the United States and other Countries; Public Aid to Railway Construction; Relation of the Railways to the State in the United Kingdom and France; Relations of the Railways and the State in Italy and Germany; Regulation of Railways by the American State Governments; Railway Regulation by the Federal Government; The Courts and Railway Regulation; Railway Taxation; The Problem of Government Regulation. There is an index of six pages.

AMERICAN RAILWAYS.

By Edwin A. Pratt. Reprinted (with additions) from *The Times*. Cloth, 8 x 5 ins., 8 + 307 pp. New York, The Macmillian Company, 1903. $1.25.

The facts here given were collected during a four months tour of the United States, made in the winter of 1902-3, and representing a total about 9 000 miles of railway traveling on the American continent. While seeking to put before the representatives of railway interests in England a certain amount of practical information which might be of service to them, the author has also aimed at interesting the general reader in the subject of American railways, in regard alike to their origin, their characteristics, and their operation. He has also incorporated some references to the present-day expansion of those agricultural, industrial, and commercial interests of the United States to which, more than to passenger traffic, the railways of the United States are indebted for their prosperity. The chapter headings are: A General Survey; Some Points of Difference; The Growth of Freight; Wagons and Locomotives; The Passenger Business; On the Cars; The Pittsburg Block; Track Elevation in Chicago; Across the

Prairies; In the Rockies: A Mining Camp Railway in Chicago; The Santa Fé Trail; The Trans-Continental Traffic; Gardens, Deserts, and the New Galveston; Progress in the South; The North-West and Its Story; The New England States; Railway Accidents in the United States.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK, 1904.

Edited by William H. Fowler, M. Inst. C. E., M. I. Mech. E. Leatherette, 6 x 4 ins., 95 + 441 pp., illus. Scientific Publishing Co., Manchester. 1 shilling, 6 pence, net.

Advantage has again been taken in the preparation of the 1904 edition of this pocket-book to revise its contents in order to bring the matter up to date and correct any typographical errors not previously detected. In several directions this work of revision and addition has assumed considerable dimensions, and it is hoped that it will prove of corresponding value. The section on gas engines has been largely rewritten with the intention of making it of special value to all interested in gas engine design and practice. There is an index of seventeen pages.

Gifts have also been received from the following:

Ala.—Geological Surv. 1 pam.
Albemarle & Chesapeake Canal Co. 1 bound vol.
Am. Ry. Master Mechanics' Assoc. 1 bound vol.
Am. St. Ry. Assoc. 1 vol.
Am. Water-Works Assoc. 1 vol.
Architekten-Verein zu Berlin. 2 pam.
Atlanta & West Point R. R. Co. 1 pam.
Boston, Mass.—Pub. Lib. 1 vol.
Buffalo, Rochestet & Pittsburgh Ry. Co. 1 pam.
Butler, D. B. 1 pam.
Canadian Pacific Ry. Co. 1 pam.
Cantor, Jacob A. 2 pam.
Central of Georgia Ry. Co. 1 pam.
Central R. R. Co. of N. J. 1 pam.
Chicago & Alton Ry. Co. 1 pam.
Chicago, Burlington & Quincy R. R. Co. 1 pam.
Chicago, Milwaukee & St. Paul Ry. Co. 1 pam.
Chicago, Rock Island & Pacific Ry. Co. 1 pam.
City Record. 2 bound vol.
Cleveland, Cincinnati, Chicago & St. Louis Ry. Co. 1 pam.
Colby, Albert Ladd. 1 pam.
Colorado & Southern Ry. Co. 1 pam.
Conn.—Agri. Exper. Station. 1 pam.
Corthell, E. L. 1 bound vol.
Crandall, C. L. 1 pam.
Denver & Rio Grande R. R. Co. 2. pam.
Detroit, Mich.—Dept. of Pub. Works. 1 bound vol.
Duluth, Minn.—City Officers. 1 vol.
Eng. Soc. Polytechnic Inst. of Brooklyn. 1 bound vol.
Eng. Soc. School of Practical Sci., Toronto. 2 vol.
Erie R. R. Co. 1 pam.
Fisk, W. L. 2 pam., 1 map.
Fitchburg, Mass.—City Clerk. 16 bound vol., 2 vol.
Fort Worth & Denver City Ry. Co. 1 pam.
Grand Rapids, Mich.—City Engr. 1 pam.
Great Britain—Patent Office. 7 vol., 4 pam.
Great Northern Ry. Co. 2 pam.
Griggs, Julian. 1 pam.
Hawaii—Territorial Meteorologist. 4 pam.
Ill.—R. R. & Warehouse Comm. 1 map.
Ill. Soc. of Engrs. and Surv. 1 vol.
Inst. of Civ. Engrs. 1 bound vol., 2 vol.
Iowa—Geological Surv. 1 bound vol.
Journal of the U. S. Artillery. 1 pam.
Lake Mohonk Conference on International Arbitration. 1 pam.
Lehigh Valley R. R. Co. 3 pam.
Louisville & Nashville R. R. Co. 1 pam.
Maine—State Board of Health. 6 bound vol., 5 vol.
Md —State Board of Health. 4 vol.
Mass.—Bureau of Statistics of Labor. 2 bound vol.
Mead, Elwood. 1 bound vol.
Montclair, N. J.—Board of Health. 1 pam.
Montreal, Que.—Supt. of Water-Works. 1 pam.
N. H.—R. R. Commrs. 5 vol.
N. J.—Geological Surv. 1 pam.
New London, Conn.—Board of Water Commrs. 1 pam.
N. Y.—Commr. of the State Reservation at Niagara. 5 pam.
N. Y.—Comptroller. 7 bound vol., 24 pam.
N. Y.—Forest, Fish & Game Comm. 1 pam.
N. Y.—Pub. Lib. 1 pam.
New York Central & Hudson River R. R. Co. 1 pam.
New York, New Haven & Hartford R. R. Co. 2 pam.
New York, Ontario & Western Ry. Co. 2 pam.
New York, Susquehanna & Western R. R. Co. 1 pam.
Norfolk, Va.—Board of Water Commrs. 1 pam.
North of England Inst. of Min. and Mech. Engrs. 1 pam.
North-East Coast. Inst. of Engrs. and Shipbuilders. 1 bound vol.
Ogdensburg, N. Y.—City Clerk. 1 pam.
Ohio—Commr. of Railroads & Telegraphs. 1 bound vol.
Parsons, Wm. Barclay. 2 bound vol.
Queensland—Commr. for Rys. 1 pam.
Reading Co. 2 pam.
Rock Island Co. 1 pam.
Ruttan, H. N. 1 pam.
Santa Fé, Prescott & Phœnix Ry. Co. 1 pam.
Smithsonian Inst. 2 bound vol.
Southern Ry. Co. 2 pam.
Spring, F. J. E. 1 pam.

Thompson, R. A. 1 pam.
Tombo, Carl. 3 pam.
U. S. Bureau of Statistics. 1 vol.
U. S. Chf. of Engrs. 14 specif.
U. S. Dept. of Agri. 1 pam.
U. S. Geological Surv. 1 pam.
U. S. Interstate Commerce Comm. 1 bound vol., 3 vol.
U. S. War Dept. 2 vol.
Univ. of Ariz. 1 pam.
Univ. of Ill. 1 bound vol.
Univ. of Pa. 1 vol.
Western Ry. of Alabama. 1 pam.
Wilmington, Del.—Board of Health. 1 pam.
Wis.—State Board of Health. 3 bound vol., 2 vol., 3 pam.
Yonkers, N. Y.—Dept. of Pub. Works. 1 pam.

BY PURCHASE.

Continuous Current Dynamos and Motors and their Control. Being a Series of Articles Reprinted from *The Practical Engineer*, and completed by W. R. Kelsey. London, The Technical Publishing Company, Limited, 1903.

Electrical Influence Machines; Their Historical Development and Modern Forms, with Instructions for Making Them. By John Gray. Second Edition, Revised and Enlarged. New York, D. Van Nostrand Company, 1903.

Das Elektrische Kabel. Eine Darstellung der Grundlagen für Fabrikation, Verlegung und Betrieb. Von C. Baur. Berlin, Julius Springer, 1903.

Modern Practical Electricity. Electricity in the Service of Man. A Popular and Practical Treatise on the Applications of Electricity in Modern Life. By R. Mullineux Walmsley. Vol. 1–3. Chicago, W. T. Keener & Co.

The "Engineering" and Electric Traction Pocket-Book. By Philip Dawson, Assoc. M. Inst. C. E., M. I. Mech. E., M. I. E. E. London, Offices of "Engineering." New York, John Wiley and Sons, 1903.

Mechanics of Engineering. Theoretical Mechanics, with an Introduction to the Calculus. Designed as a Text-Book for Technical Schools and Colleges, and for the Use of Engineers, Architects, etc. By Julius Weisbach. Translated from the Fourth Augmented and Improved German Edition, by Eckley B. Coxe. Ninth American Edition. New York, D. Van Nostrand Company, 1899.

Mechanics of Engineering and of Machinery. By Julius Weisbach. Vol. II, Section II, Part II, Translated from the Fourth Augmented and Improved German Edition by A. Jay Du Bois, with Additions Showing American Practice by R. H. Buel; Vol. III, Pt. I, Sections I–II, Second Edition, Thoroughly Revised and Enlarged by Gustav Herrmann, Translated by J. F. Klein. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1896–1902.

The Gas-Engine. A Treatise on the Internal-Combustion Engine Using Gas, Gasoline, Kerosene, or other Hydrocarbon as Source of Energy. By Frederick Remsen Hutton. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1903.

The Practical Physics of the Modern Steam Boiler. By Frederick J. Rowan, A. M. Inst. C. E., M. I. E. S. With a Preface by Prof. R. H. Thurston. New York, D. Van Nostrand Company, 1903.

Lead-Smelting. The Construction, Equipment and Operation of Lead Blast Furnaces, and Observations on the Influence of Metallic Elements on Slags and the Scientific Handling of Smoke. By Malvern Wells Iles. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1902.

The Mineral Industry; Its Statistics, Technology and Trade in the United States and other Countries to the End of 1902. Founded by the late Richard P. Rothwell. Edited by Joseph Struthers. Vol. XI Supplementing Volumes I to X. New York and London, *The Engineering and Mining Journal*, 1903.

House Drainage Manual. A Guide to the Design and Construction of Systems of Drainage and Sewage Disposal from Houses. By Wm. Spinks, Assoc. M. Inst. C. E. Second Edition, Revised and Extended by E. H. Blake. With Tables, Illustrations, Extracts from Public Health Acts, Metropolis Management Acts, and Model By-Laws Relating to House Drainage. Biggs & Co., London; D. Van Nostrand Company, New York, 1903.

Die Angewandte Elastizitäts- und Festigkeitslehre. Auf Grund der Erfahrung bearbeitet von L. v. Tetmajer. Zweite, vollständig umgearbeitete Auflage. Leipzig und Wien, Franz Deuticke, 1904.

Die Gesetze der Knickungs- und der Zusammengesetzten Druck-festigkeit der technisch wichtigsten Baustoffe. Bearbeitet von L. v. Tetmajer. Dritte vervollständigte Auflage. Leipzig und Wien, 1903.

SUMMARY OF ACCESSIONS.

October 13th to November 10th, 1903.

Donations (including 10 duplicates)	230
By purchase	16
Total	246

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
BENNETT, FREDERICK WAGONER. Cape May Court House, N. J		Oct. 7, 1903
BERLE, KORT. Brookland, D. C	Assoc. M.	Dec. 6, 1899
	M.	Nov. 4, 1903
COLBY, ALBERT LADD. Care, International Nickel Co., 43 Exchange Pl., New York City		Oct. 7, 1903
DAUCHY, WALTER EDWARD. Supt., Heating Dept., Erie City Iron Works, 7153 Princeton Ave., Chicago, Ill		Nov. 4, 1903
DAVIS, JOHN ROSE WILSON. Engr., M. of W., G. N. Ry., Merchants' Hotel, St. Paul, Minn		Nov. 4, 1903
HARAHAN, WILLIAM JOHNSON. Asst. Gen. Mgr., Ill. Cent. R. R., Chicago, Ill	Assoc. M.	Oct. 3, 1894
	M.	Oct. 7, 1903
HOLLYDAY, RICHARD CARMICHAEL. Engr. in Chg., New York Navy Yard, Brooklyn, N. Y		Sept. 2, 1903
JOHNSON, CHAPMAN LOVE. Superv. Engr., McDonough Constr. Co., Tomhannock, N. Y		Oct. 7, 1903
MATHESON, DONALD ALEXANDER. Engr., Caledonian Ry., Buchanan St. Station, Glasgow, Scotland		Oct. 7, 1903
PATRICK, MASON MATHEWS. Instr. of Practical Military Eng., U. S. Military Academy, West Point, N. Y		Oct. 7, 1903
PHILLIPS, ARTHUR LOUIS. Asst. Chf. Engr., Chic., St. L., Memphis & N. O. R. R., 536 Randolph Bldg., Memphis, Tenn		Nov. 4, 1903
SHEARWOOD, FREDERICK PERRY. Care, Dominion Bridge Co., Lachine Locks, Que., Canada		Oct. 7, 1903
TUCKER, ROSS FRANCIS. Pres., Tucker & Vinton, 156 Fifth Ave., New York City		Oct. 7, 1903
WHISTLER, John T. U. S. Geological Survey (Res., 1823 Kalorama Ave.), Washington, D. C	Assoc. M.	Jan. 2, 1901
	M.	Oct. 7, 1903

ASSOCIATE MEMBERS.

BEERBOWER, GEORGE MARSHALL. Engr., N. Y. Zoological Society, 183d St. and Southern Boulevard, New York City		Oct. 7, 1903
CUNNINGHAM, JOHN MILLER. West Pittsburg, Lawrence Co., Pa		Oct. 7, 1903
DREW, CHARLES DAVIS. 6 Kirkland Rd., Cambridge, Mass.		Oct. 7, 1903
HARBY, ISAAC. Civ. Engr. with John A. Roebling's Sons Co., 301 Spring St., Trenton, N. J	Jun.	June 6, 1899
	Assoc. M.	May 6, 1903
HENGST, ROBERT GRAHAM. Asst. Chf. Engr., West. Allegheny R. R. Co., 301 Smithfield St., Pittsburg, Pa		Oct. 7, 1903

		Date of Membership.
MONSARRAT, NICHOLAS DAUBENEY. Chf. Engr., Sunday Creek Coal Co., 432 E. Broad St., Columbus, Ohio	Jun.	Feb. 5, 1895
	Assoc. M.	Sept. 2, 1903
WINSOR, FRANK EDWARD. 367 Boylston St., Boston, Mass		Nov. 4, 1903

ASSOCIATES.

WILGUS, HERBERT SEDGWICK. Prin. Asst. Engr., The Brooklyn Heights R. R. Co., 166 Montague St., Brooklyn, N. Y.	Jun.	Oct. 1, 1901
	Assoc.	Nov. 3, 1903

JUNIORS.

BRASLOW, BARNETT. 59 East 115th St., New York City	Nov. 3, 1903
CAMERON, KENNETH MACKENZIE. Chf. Engr.'s Office, Canadian Pacific Ry., Windsor St. Station, Montreal, Que., Canada	Oct. 6, 1903
COOPER, KENNETH FARRA. Smith Creek, via San José, Cal	Oct. 6, 1903
DOTY, JOHN WILLIAMS. Care, Foundation & Contr. Co., 35 Nassau St., New York City	Nov. 3, 1903
HANNA, WALTER SCOTT. Care, The Am. Pipe Mfg. Co., 112 North Broad St., Philadelphia, Pa.	Oct. 6, 1903
HOYT, HENRY PEREZ. Asst. Engr., Great Northern Paper Co., Millinocket, Me	Oct. 6, 1903
IRELAND, MARK LORIN. Ordnance Office, War Dept., Washington, D. C	Oct. 6, 1903
LILLICH, JOSEPH THOMAS. 514 Rialto Bldg., St. Louis, Mo	Nov. 3, 1903
MCCRORY, SOL. Box 254, Shreveport, La	Oct. 6, 1903
POLK, ARMOUR CANTRELL. 20 West 34th St., New York City.	Oct. 6, 1903
PORTER, JOHN ENDICOTT. Vilas, Pa	Sept. 1, 1903
SAWYER, WILBUR CYRUS. Care, U. S. Geological Survey, Washington, D. C	Oct. 6, 1903
SCHMID, FRANCIS RAUCH. 30 Wall St., Bethlehem, Pa	Oct. 6, 1903
STRATTON, CHARLES HEYWOOD. 195 Hanover St., Annapolis, Md	Oct. 6, 1903

CHANGES OF ADDRESS.

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ANDERSEN, CHRISTIAN.....P. O. Box 532, Spokane, Wash.

ANTHONY, CHARLES, JR..... Town Hall, East London, Cape of Good Hope, South Africa.

APPLETON, THOMAS.....Supt. of Constr., Public Bldgs., Holyoke, Mass.

DAVIS, ARTHUR POWELL.....Superv. Engr., U. S. Reclamation Service, Phœnix, Ariz.

EDWARDS, HARRY WINTER.....Care, Chihuahua & Pacific R. R., Apartado 46, Chihuahua, Mexico.

FITCH, CHARLES LINCOLN.....510 Manning Chambers, Toronto, Ont., Canada.

FLAD, EDWARD.....Cons. Engr., 1009 Fullerton Bldg., St. Louis, Mo.

FLAGG, JOSIAH FOSTER.....Care, Maurice Lindsay, Tenafly, N. J.

FRAZIER, HARRY.....Cons. Engr., Seaboard Air Line Ry., 827 W. Grace St., Richmond, Va.

FRINK, ELLIS ALEXANDER.....(Frink & Hazen, Cons. and Contr. Engrs.), 711 Union Trust Bldg. (Res., Hotel Condon, Fayette and Paca Sts.), Baltimore, Md.

HANSEL, CHARLES .....Care, Pneumatic Signal Co., Rochester, N. Y.

HASKINS, WILLIAM JEWETT.....Cons. Engr. and Contr., 32 Broadway, New York City.

HOFFMAN, NATHANIEL BAKER KLINK....Asst. Engr., Dept. of Sewers, Bronx, 1 Nelson Ave., New York City.

HOUGH, ULYSSES B.....707 W. 16th St.. Los Angeles, Cal.

KAUFMAN, GUSTAVE.....26 Court St., Room 54, Brooklyn, N. Y.

KUNZ, FREDERIC CHARLES.....Cons. Engr., Dept. of Bridges, New York City.

LIST, CHARLES .....628 Sutter St., San Francisco, Cal.

LOWRIE, HARVEY CHILDS.....Pres., The Lowrie Safe & Lock Co., 118 West Jackson Boulevard, Chicago, Ill.

MCCULLOH, ERNEST.....Chf. Engr., Yakima Development Co., 1 Wilson Blk., North Yakima, Wash.

MCKINSTRY, CHARLES HEDGES.....Capt., Corps of Engrs., U. S. A., U. S. Engr. Office, Los Angeles, Cal.

O'ROURKE, JOHN FRANCIS.....Pres., O'Rourke Eng. Const. Co., 26 Nassau St., New York City.

SCHULTZ, ALBERT LOUIS.....817 North Highland Ave., Pittsburg, Pa.

THOMSON, GEORGE HUNTINGTON.....Care, The Transportation Club, 42d St. and Madison Ave., New York City.

TUCKER, LESTER WALDO.....34 Banks St., West Somerville, Mass.

TUCKEY, THOMAS WILLIAM TOWNSEND....Dist. Engr., Imperial Rys. of North China, Tientsin, North China.

WEBER, ALEXANDER HAMILTON.....U. S. Asst. Engr., Room 507, Colorado Bldg., Washington, D. C.

WIMMER, SEBASTIAN.....St. Marys, Elk Co., Pa.

ASSOCIATE MEMBERS.

BRAUNE, GUSTAVE MAURICE.....202 Locust St., Harrisburg, Pa.

COMSTOCK, CHARLES WORTHINGTON.....Prof. of Min. Eng., Colorado School of Mines, Golden, Colo.; Address, 213 Boston Bldg., Denver, Colo.

COVERDALE, WILLIAM HUGH .....9 West 30th St., New York City.
DIMON, DANIEL YOUNG.....Care, Milliken Bros., 11 Broadway, New York City.
GARDINER, FREDERICK WILLIAM.....Asst. Engr., Manhattan Ry. Co., 32 Park Pl., New York City.
HAZARD, ERSKINE.....Box 3197, Johannesburg, Transvaal, South Africa.
HOLMES, GLENN DICKINSON.....7 Prospect Ave., Batavia, N. Y.
LEAVENWORTH, GEORGE STEVENS.....Chf. Engr., Powers & Mansfield Co., 280 River St., Troy, N. Y.
LEFFINGWELL, FRANK DODGE.....54 Elmwood Ave , Montclair, N. J.
LINDSEY, JOHN BROWN, JR.....Supt., West Pascagoula Creosote Works, Gautier, Miss.
MACNEILLE, PERRY ROBINSON .....Cons. Engr., 230 Fourth Ave., W., Roselle, N. J.
MCDARGH, HARRY JOHN.....Cons. Civ. and Hydr. Engr. (Folsom & McDargh), Fifth Floor, Conover Bldg., Dayton, Ohio.
MESA, ANTONIO ESTEBAN.....Animas 100, Havana, Cuba.
OSBOURN, HENRY VAN BUREN. .....Tucson, Ariz.
ROY, ROBERT MAITLAND.....270 Main St., West, Hamilton, Ont., Canada.
SHIMA, TAKEJIRO. .....Bei Frau Bierwagen, Bayreüther Str. 27/h, Berlin, W., Germany.
STRAWN, THOMAS CORWIN .....211 West 101st St., New York City.
TOMPKINS, EDWARD DE VOE.....63 West 56th St., New York City.
WEBB, WALTER LORING.....Cons. Engr., 810 Girard Bldg., Philadelphia, Pa.
WHEELER, RALPH NORMAN.....Asst. Engr., Rapid Transit R. R. Comm., 120 Liberty St., New York City.
WILSON, HENRY FELIX, JR.....Civ. and Min. Engr., 204 First National Bank Bldg., Birmingham, Ala.

ASSOCIATES.

TURRILL, SHERMAN MARSH.....114 Willoughby St., Brooklyn, N. Y.
YOUNG, CHARLES GRIFFITH .....Care, J. G. White & Co., 43 Exchange Pl., New York City.

JUNIORS.

CRAWFORD, JOSEPH EMMANUEL.....Hotel Roanoke, Roanoke, Va.
HAMMER, ROBERT HENRY .....205 Congress St., Brooklyn, N. Y.
HARSHBARGER, ELMER DWIGHT.....Care, Chic. & East. Ill. R. R. Co., Ogden, Ill.
LINDSEY, KIEFFER.....Box 74, Station W, Brooklyn, N. Y.
MINER, JAMES HENRY.....Draftsman, C., R. I. & P. Ry., 299 La Salle Ave., Chicago, Ill.

PAINE, GEORGE HEBARD.....Cons. Engr., 8th Floor, St. Paul Bldg., New York City.
PEARSE, LANGDON.....Box 203, Augusta, Me.
ROHNERT, BENNO .....U. S. Asst. Engr., Amherstburg, Ont., Canada.
SHRYOCK, JOSEPH GRUNDY.....Care, Virginia Bridge & Iron Co., Roanoke, Va.
SPENCER, LOUIS BERNARD.....Box 487, Ogden, Utah.
VAN PELT, SUTTON.....Care, U. S. Engr. Office, Tuscaloosa, Ala.
WELLER, FRANCIS REPETTI.....1416 F St., Washington, D. C.
WILHELM, JEROME FREDERICK.....Traverse City, Mich.

FELLOWS.

ADAMS, EDWARD DEAN.....455 Madison Ave., New York City.

DEATHS.

GREENE, CHARLES EZRA.....Elected Member, January 4th, 1882; died October 17th, 1903.
THURSTON, ROBERT HENRY.....Elected Member, December 6th, 1871; died October 25th, 1903.
LATHAM, NORMAN SMITH.....Elected Junior, July 3d, 1889; died November 10th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(October 14th to November 10th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brusseis, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.

LIST OF ARTICLES.

Bridge.

The Burnett and Kennedy Bridges, Bundaberg, Queensland.* Alfred Joseph Goldsmith M. Inst. C. E. (63) Vol. 153.
Building the Cabul River Bridge in India. (14) Oct. 17.
The Adda Railway Bridge in Italy.* (14) Oct. 17.
The Concrete Viaduct near Riverside, Cal.; San Pedro, Los Angeles and Salt Lake R. R. A. C. Ostrom. (13) Oct. 22.
A Novel Type of Drawbridge.* (13) Oct. 22.
Novel Method of Erection Adopted for the Frans Bridge at Villefranche over the Saône.* (13) Oct. 22.
A New High Level Bridge over the River Tyne at Newcastle, on the Northeastern Railway of England.* F. E. Harrison. (40) Oct. 23.
A Movable Railway Incline Bridge at New Orleans.* (14) Oct. 24.
Falsework for Rocky Bottoms in Rapid Currents.* (Abstract of Report of a Committee to the Assoc. of Ry. Supts. of Bridges and Bldgs.) (18) Serial beginning Oct. 24.
Flood Damage to Bridges at Paterson, N. J.* (13) Oct. 29.
Methods of Making Annual Inspection of Bridges and Culverts. (Abstract of Report of Committee of the Assoc. of Ry. Supts. of Bridges and Bldgs.) (13) Oct. 29.
The Kansas City Flow-Line Bridge Repairs.* J. A. L. Waddell, M. Am. Soc. C. E. (13) Oct. 29; (14) Oct. 31; (15) Oct. 30.
Temporary Arrangement to Carry Traffic where One Arm of a Drawbridge is Wrecked.* (Abstract of Report of a Committee to the Assoc. of Ry. Supts. of Bridges and Bldgs.) (18) Oct. 31.
A Concrete Arch Bridge near Mechanicsville, N. Y.* (13) Nov. 5.
Erection of the Grand Rapids Bridge.* (14) Nov. 7.
Calcul d'un Arc de Forme Quelconque: Exposé de la Méthode de de Dion dans Toute Sa Généralité Suivi d'une Application Numérique.* L. Lemaire. (30) Oct.
Reconstruction du Pont de Frans sur la Saône, à Villefranche.* (33) Oct. 31.

Electrical.

Reverse Current Circuit Breakers and the Protection of Transmission Lines.* Leonard Wilson. (42) Aug.
Methods of Bringing High Tension Conductors into Buildings.* C. E. Skinner. (42) Aug.
The Grounded Wire as a Protection against Lightning. Ralph D. Mershon. (42) Aug.
The Testing of Electrical Apparatus for Dielectric Strength. P. H. Thomas. (42) Aug.
Choice of Frequency for Very Long Lines. P. M. Lincoln. (42) Aug.
Y or Δ Connection of Transformers.* F. A. Blackwell. (42) Aug.
Electric Cables for High Voltage Service. Henry W. Fisher. (42) Aug.
The Operation and Maintenance of High-Tension Underground Systems.* Philip Torchio. (42) Aug.
The Use of Automatic Means for Disconnecting Disabled Apparatus. H. G. Stott. (42) Aug.
Storage Battery Industrial Locomotives.* F. L. Sessions. (42) Aug.
Energy Transformations in the Synchronous Converter. Wm. S. Franklin. (42) Aug.
Commercial Alternator Design.* W. L. Waters. (42) Aug.
Electric Power in Mill and Factory.* Charles W. Startsman. (69) Serial beginning Oct.
Electric Shipbuilding Cranes at Kiel.* (12) Oct. 9.
On Single-Phase Repulsion Motors. William Cramp. (Paper read before the British Assoc. for the Advancement of Science.) (11) Oct. 9.
The Glasgow Municipal Telephone System. (26) Serial beginning Oct. 9.
The Bexley Electric Lighting and Tramway Undertaking.* (26) Oct. 9.
Experiments for Improving the Construction of Practical Standards for Electrical Measurements. (Report of Committee of the British Assoc. for the Advancement of Science.) (26) Serial beginning Oct. 9.
The Parallel Working of Alternators. B. Hopkinson. (Abstract of paper read before the British Assoc. for the Advancement of Science.) (26) Oct. 9.
Electric Light and Power Engineering.* (47) Serial beginning Oct. 10.
The First Transmission of Energy in Europe by Means of Triphase Currents.* Emile Guarini. (19) Oct. 17.
The Electric Light and Power Situation in St. Louis.* (27) Oct. 17.
The Co-Operative Telephone Company's System at Detroit, Mich.* (27) Oct. 17.
A Combined Street Railway and Lighting Plant at Muskegon, Mich.* (14) Oct. 17.
Practical Examples with the Calculator Board: Series I, Notes for Submarine Cable Staffs.* Edward Raymond-Barker. (26) Serial beginning Oct. 23.
Transmission of Hudson River Power.* (27) Serial beginning Oct. 24.
On the Mechanism of Electric Power Transmission. A. E. Kennelly. (27) Oct. 24.
The Stone Wireless Telegraph System. Louis Duncan. (27) Oct. 24.
Photometric Tests of the Nernst Lamp.* (27) Oct. 24.
Alternating Current Generators at Preston.* (11) Oct. 30; (12) Oct. 30; (26) Oct. 30; (57) Oct. 30.

*Illustrated.

Electrical—(Continued).

Steam Turbo-Electric Generating Plants. George Wilkinson. (Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Oct. 31; Abstract (26) Oct. 30.
An Improved Method of Testing Large Alternators under Full Load Conditions. B. A. Behrend. (27) Oct. 31.
Notes on Certain Three-Wire Systems.* Charles T. Mosman. (Paper read before the Ohio Elec. Light Assoc.) (27) Oct. 31.
Motors in an Elevator Factory and Machine Shop.* (27) Oct. 31.
Motor-Driven Machine Tools.* (25) Nov.
Electric Searchlights; Their Use Afloat and Ashore.* Frank C. Perkins. (10) Nov.
The Care of Switchboards.* Edwin W. Creed. (64) Nov.
Some Practical Points in the Design of Direct-Current Dynamo-Electric Machines.* Cecil P. Poole. (3) Nov.
Static Discharges in Electric Circuits. Percy H. Thomas. (3) Nov.
Factory Turbo-Generator and Electric Power Distributing Plant.* (27) Nov. 7.
Dublin Three-Phase Central Station.* (27) Nov. 7.
The Electrical Drive for Machine Tools. Robert Lozier. (27) Nov. 7.
The Steam Turbine Installation of the B. F. Goodrich Company.* (14) Nov. 7.
Appareil Électrique pour le Chargement des Cornues à Gaz: Système P. Sarrasin. (34) Oct.
Installation Électrique des Hauts Fourneaux de la Société *Elba*.* (33) Oct. 24.

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The Latest Battleships for the United States Navy.* (46) Oct. 17.
The Imperial German Navy.* Archibald S. Hurd. (10) Nov.
The Steamship of the Future, Greater Safety, Comfort, Size and Speed.* Stephen P. M. Tasker. (10) Nov.
Bassin de Radoub de la Compagnie des Chantiers Kawasaki, à Kobé (Japon).* (35) Oct.
Le Paquebot *Kaiser Wilhelm II.** J. Bousquet. (33) Serial beginning Oct. 3.
Les Moteurs à Pétrole à Bord des Voiliers de Pêche. C. Birault. (33) Oct. 31.

Mechanical.

Mechanical Handling of Material.* George Frederick Zimmer, Assoc. M. Inst. C. E. (63) Vol. 153.
Design of Sheaves and Drums for Wire Rope. Samuel Diescher. (58) Sept.
High Grade Wire Rope. L. C. Moore. (58) Sept.
Timber Treating Plants.* W. W. Curtis. (4) Oct.
A Consideration of the Gaseous Fuel Problem. Henry G. Morris. (2) Oct.
Air Separation of Cement (Description of Apparatus).* W. Michaelis, Jr. (67) Oct.
The Industrial Haulage System.* Hrolf Wisby. (69) Oct.
Constructional Details and Costs of Recent Extensions (1900-1902), with Notes on Working Results, at the Tynemouth Gas Works, North Shields.* A. Clement Hovey. (Paper presented to the North of England Gas Mgrs. Assoc.) (66) Oct. 6.
The Eitle Retort-Charging Machines.* (66) Oct. 6.
Borsigs Works.* (11) Serial beginning Oct. 9.
On the Design and Testing of Centrifugal Fans for Induced Draught and Other Purposes. W. Gilbert, A. M. I. C. E. (Paper read before the Civil and Mech. Engrs. Soc.) (11) Oct. 9.
A Simplified Method of Gas Purification to Completely Recover Tar and Ammonia.* (66) Oct. 13.
Manufacture and Uses of Carborundum. F. A. J. Fitzgerald. (Paper read before the Philadelphia Foundrymen's Assoc.) (20) Oct. 15.
Mechanical Road Vehicles. W. Worby Beaumont, M. Inst. C. E. (29) Serial beginning Oct. 16.
Hydraulic Coal Hoist at Glasgow Harbour.* (12) Oct. 16.
Wrightson's Patent Coal Shipper.* (57) Oct. 16.
A 66-Foot Vertical Boring Machine.* (12) Oct. 16.
Commercial Wrought-Iron and Steel Pipe. Franklin Riffle, M. Am. Soc. C. E. (Abstract of Paper read before the Pacific Coast Gas Assoc.) (47) Oct. 17.
Developments in Automobile Construction. T. Clarkson. (Paper read before the British Assoc. for the Advancement of Science.) (47) Serial beginning Oct. 17.
Notes on the Construction of Inclined Retort Settings.* Archd. S. B. Little. (66) Serial beginning Oct. 20.
Modernizing a Large Foundry.* (20) Oct. 22.
Advantages of Steam Turbines for Textile Mills. Austin R. Dodge. (Paper read before the New England Cotton Mfrs. Assoc.) (13) Oct. 22.
Diagrams for Estimating Hydraulic Machinery. Frank B. Kleinhaus. (13) Oct. 22.
The Miller System of Mechanical Refrigeration.* (15) Oct. 23.
Kilroy's Stoking Indicator.* (26) Oct. 23.
A New Continuous Process for Making Ingot Moulds.* (11) Oct. 23.
The Newcomen Engine* Henry Davey. (Paper read before the Inst. of Mech. Engrs.) (11) Serial beginning Oct. 23; (12) Serial beginning Oct. 23; (22) Oct. 23.
The Reversibility of Thermodynamics. J. Swinburne. (Abstract of Paper read at the British Assoc. for the Advancement of Science.) (47) Oct. 24.
A New Geared Speed Changing Device.* (20) Oct. 29.

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*Illustrated.

Mechanical—(Continued).

Rapid-Cutting Tool Steels. (11) Serial beginning Oct. 30; (12) Oct. 30.
Observations Upon the Sub-Aqueous Storage of Steam Coal. J. Macaulay. (12) Oct. 30.
Reverse Curves Rolling Mill.* (12) Oct. 30.
Steam Turbo-Electric Generating Plants. George Wilkinson. (Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Oct. 31; Abstract (26) Oct. 30.
Modern Cylindrical Grinding.* C. H. Norton. (Abstract of Paper read before the Cincinnati Metal Trades Assoc.) (47) Oct. 31.
Motors in an Elevator Factory and Machine Shop.* (27) Oct. 31.
The Foundry and Town of Trafford City, Pa.* (14) Oct. 31.
Works of the Marine Engine & Machine Company.* (14) Oct. 31.
The Central Heating Plants of Indianapolis. W. K. Eldridge. (Paper read before the Amer. Soc. of Mun. Impvts. (60) Nov.; Abstract (13) Nov. 5.
Motor-Driven Machine Tools.* (25) Nov.
Natural Gas in Steam Production.* W. R. Crane. (45) Nov.
A New Type of Air Compressor.* W. H. Booth. (45) Nov.
Electric Steam and Hydraulic Shears at German Steel Works.* Frank C. Perkins. (41) Nov.
Recent Developments in the Production of Water Gas.* A. Humboldt Sexton. (9) Nov.
Special Features in the Design of Locomotive Boilers and Fireboxes.* Chas. S. Lake. (9) Nov.
Superheated Steam for Steam Engines; With Special Reference to the McPhail & Simpson's System.* John Goodman, M. Inst. C. E. (10) Nov.
Fuel Losses in Steam Plants, and How to Determine Them. George H. Barrus. (10) Nov.
Oil-Fired Furnaces.* A. M. Bell, M. Inst. M. E. (10) Nov.
Notes on the Operation of Large Carburetted Water Gas Sets. W. Cullen Morris. (Paper read before the Amer. Gas Light Assoc.) (24) Nov. 2.
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THE BREAKWATER AT BUFFALO, NEW YORK.

By Emile Low, M. Am. Soc. C. E.

To be Presented December 16th, 1903.

The City of Buffalo, N. Y., situated at the foot of Lake Erie, is practically the eastern terminus of most of the lake traffic, the natural barrier intervened by the Falls of Niagara River preventing water communication with Lake Ontario, except through the inadequate Welland Canal. This natural obstruction has aided in building up a large commercial city, with an immense water traffic.

The present harbor of Buffalo may be said to be made up of two parts, one comprising the inner harbor, formed by the natural stream, Buffalo Creek, and the artificial channel, named the City Ship Canal; and the other, the outer harbor, formed by a chain of breakwaters, extending southeast along the lake front, from Fort Porter to Stony Point, a distance of more than 5 miles.

With hardly an exception, the grain elevators, freight and storage warehouses, and coal-transfer trestles, are on the banks of the first-named, inside waterways, affording ready water communication, while access to railroads is provided by tracks, paralleling the waterways in the rear of the above-named structures.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The practical completion of the stone (or rubble-mound) section of the breakwater, in December, 1902, forged the last link in the chain of a system of harbor protection which is undoubtedly without parallel in the United States. This structure is a part of the Buffalo breakwater, known as the Extension to Stony Point, and has been building since 1897, under the direction of Major (now Colonel) Thomas W. Symons, M. Am. Soc. C. E., Corps of Engineers, U. S. Army. It may be opportune to state here that much of the matter contained in this paper has been gleaned from Government reports by this engineer officer and his predecessors, especially by Captain F. A. Mahan (now Major, retired), as well as from information and data collected by the writer in his official capacity as United States Assistant Engineer.

Historical.

As Buffalo faces the open lake, it possesses no natural harbor. The only safe place, originally, where vessels could lie, or could receive and discharge cargoes, was the area within the mouth of Buffalo Creek, which stream, previous to the construction of the harbor, was exceedingly difficult to enter, a long outer bar of gravel confining its channel inshore, and causing its entrance into the lake to be nearly parallel with the shore. For this reason the mouth of Buffalo Creek was closed to navigation most of the year, even to the smallest vessels of the time. Freshets, occasionally, opened channels across the bar, but these were soon closed again by the waves of the lake. Thus, the current of the stream and the action of the lake caused a continual shifting of the bar.

The earliest record as to the navigability of this harbor dates back to April 10th, 1818, when the Legislature of the State of New York passed an act, authorizing the survey of Buffalo Creek, with a view of building a harbor, and directing that the surveyor should be paid $3 a day for his services.

The survey was made gratuitously by the Hon. William Peacock during the summer of 1818. In order to build the harbor, the State, in 1819, loaned $12 000, on proper security, to a committee of citizens. Samuel Wilkeson superintended the construction, which was commenced in 1820, and finished in 221 days, in 1821. See piers marked *A* and *B* on Plate LVIII.

The work consisted of two parallel piers at the mouth of Buffalo Creek. The south pier was of hewn timber cribs filled with stone, and extended one-quarter mile into the lake, to 13 ft. of water. The north pier was a double row of piles filled with brush and sand. The piers concentrated the current, and practically removed the bar. The original cost of this work was $14 000.

Here it may be proper to say a few words regarding the *Walk-in-the-Water*, the pioneer steamboat above Niagara Falls. This boat was built at Black Rock, and launched on Thursday, May 28th, 1818. It was about 150 ft. in length and of 28 ft. beam. The motive power was a square, or cross-head, low-pressure engine, quite complicated in its parts, with ponderous fly-wheels and a superabundance of counter-balance weights. The main cylinder was 40 ins. in diameter, with 4-ft. stroke. The boiler was 14 ft. in diameter, with two large direct flues, and four return flues. The paddle-wheels were 15 ft. in diameter, with buckets 5 ft. long. The average speed of this boat, in favorable weather, was about 6 or 7 miles per hour. It was also rigged with two masts for carrying sail. The boat made several trips to Detroit, Mackinaw and Green Bay, and was wrecked on Thursday, November 1st, 1821, near the present south pier, during a violent gale.

In 1825 the Erie Canal was completed to Buffalo, and in 1826 the piers at the mouth of Buffalo Creek passed into the control of the United States, who rebuilt and have ever since retained charge of them.

The various projects for the formation of a harbor at Buffalo are summarized as follows:

For a proper understanding of this summary, reference is made to Plate LVIII, a map of the harbor and a portion of the city fronting thereon.

In 1830 it was determined to construct a cross- or sea- wall nearly at right angles to the eastern end of the south pier, to prevent the sea from making a breach there. In 1835 Lieutenant T. S. Brown, U. S. Engineers, submitted a project for the formation of a spacious harbor, by extending the Black Rock breakwater from Bird Island to within 1 000 ft. of the new Buffalo Lighthouse. This proposed harbor would have occupied that portion of the lake front now bounded on the north by Porter Avenue and on the south by Genesee Street. This

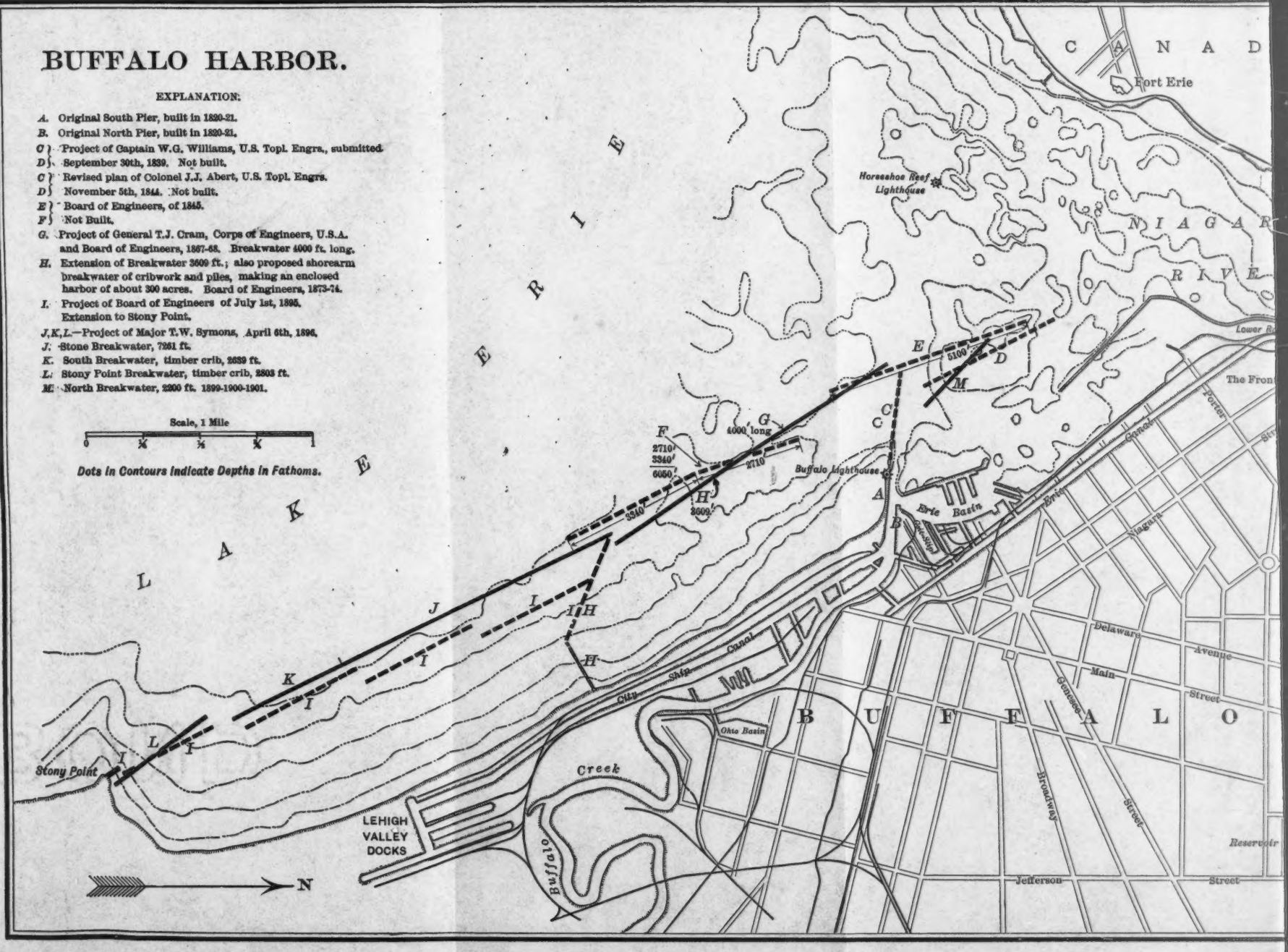
BUFFALO HARBOR.

EXPLANATION:

A. Original South Pier, built in 1820-21.
B. Original North Pier, built in 1820-21.
C } Project of Captain W.G. Williams, U.S. Topl. Engrs., submitted
D } September 30th, 1839. Not built.
C } Revised plan of Colonel J.J. Abert, U.S. Topl. Engrs.
D } November 5th, 1844. Not built.
E } Board of Engineers, of 1845.
F } Not Built.
G. Project of General T.J. Cram, Corps of Engineers, U.S.A. and Board of Engineers, 1867-68. Breakwater 4000 ft. long.
H. Extension of Breakwater 3609 ft.; also proposed shorearm breakwater of cribwork and piles, making an enclosed harbor of about 300 acres. Board of Engineers, 1873-74.
I. Project of Board of Engineers of July 1st, 1895. Extension to Stony Point.
J,K,L.—Project of Major T.W. Symons, April 6th, 1896.
J. Stone Breakwater, 7261 ft.
K. South Breakwater, timber crib, 2639 ft.
L. Stony Point Breakwater, timber crib, 2803 ft.
M. North Breakwater, 2200 ft. 1899-1900-1901.

Scale, 1 Mile
0 ¼ ½ ¾ 1

Dots in Contours indicate Depths in Fathoms.




LEHIGH
VALLEY
DOCKS

project was not adopted at the time, but was partially realized later by the construction of the Erie Basin and the Bird Island Pier by the State of New York. The latter structure forms part of the Erie Canal system, its purpose being to divert some of the waters of Lake Erie into what is called Black Rock Harbor, which, virtually, is the main feeder of the Erie Canal.

At the present time the United States Government is improving that part of the lake front lying between the south end of Bird Island Pier and the Erie Basin, by dredging it to 23 ft. This project is known as the Improvement of Lake Erie Entrance to Black Rock Harbor and Erie Basin, and was authorized by the River and Harbor Act of June 13th, 1902.

In 1837 it was proposed to extend the sea-wall southward one mile. This work was duly executed. Its location is along the beach, in a southeasterly direction from near the mouth of Buffalo Creek. Its object was to prevent the encroachment of Lake Erie. A portion of the work is an earth mound faced with masonry, the remainder is a masonry structure. Its construction was stopped in 1867, at which time it had a total length of 5 720 ft., of which there were 4 080 ft. built with coping, 1 319 ft. without coping, and 321 ft. of foundation only.

On September 30th, 1839, Captain W. G. Williams, Corps of Topographical Engineers, submitted a project for the formation of a harbor north of the mouth of Buffalo Creek, to be consummated by extending the south pier into 23 ft. of water and building a detached breakwater to protect the entrance. See projects marked *C* and *D* on Plate LVIII.

On November 15th, 1844, Colonel J. J. Abert, Corps of Topographical Engineers, reviewed this plan, stating that there is, in fact, no harbor, properly speaking, at Buffalo. There is an extensive line of wharf and dock room in the creek, at which vessels load and unload, but there is no harbor within the protection of which a revenue or national vessel can lie at anchor.

The plan recommended the construction of a breakwater upon the so-called Horse Shoe Reef, about 2 650 ft. from the northern shore; the breakwater to be about 3 700 ft. long; its western end to be about 2 100 ft. from the Black Rock pier; and its eastern end about 800 ft. from a proposed extension of the south pier, this to be extended

about 2 400 ft., so as to throw its southern extremity sufficiently beyond the breakwater on the Horse Shoe Reef. This would have given a sheltered harbor 7 400 ft. long and 2 100 ft. wide, throughout the greater part of which there would have been from 14 to 20 ft. of water.

In 1845 a Board of Engineers considered two projects for an outer harbor. The first, for a detached breakwater, 5 100 ft. long, north of the lighthouse pier, the second, also for a detached breakwater, but south of the same locality, 6 050 ft. long. See project marked *E-F* on Plate LVIII. The Board recommended the south breakwater as the most suitable, and also reported that should the demands of commerce require its extension at some future period, it might be extended even to Four-Mile Point, *i. e.*, Stony Point; and, also, that the northern one might some day become a necessity. See Fig. 1.

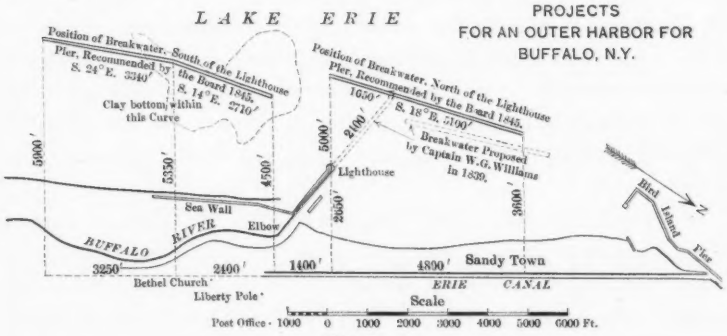
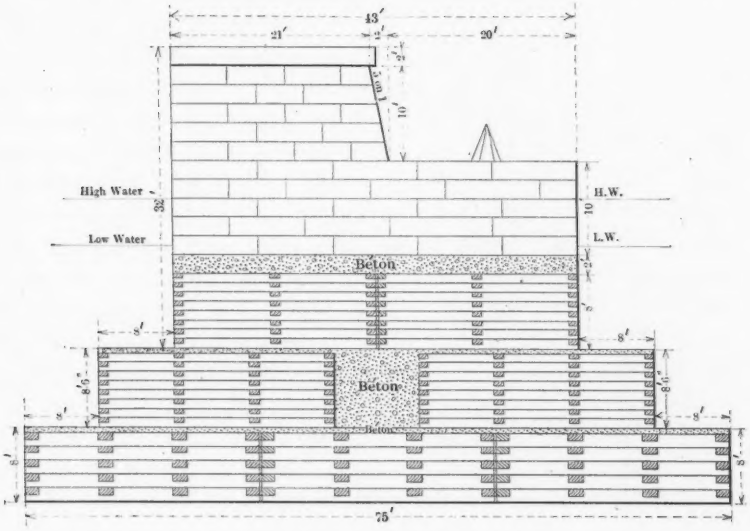


FIG. 1.

It is a matter of interest to note that the lines of these proposed breakwaters approximate closely the location of the old and north breakwaters, as actually constructed a number of years afterward, and the prophecy of the extension to Stony Point has already become an accomplished fact.

The type of structure recommended by the Board of Engineers of 1845 is shown by Fig. 2. Its essential features were three cribs under water, surmounted by a masonry structure. The lower tier (resting upon the lake bottom) to be 75 ft. wide, and composed of five courses of 18-in. square timbers. The next tier to be 59 ft. wide, eight courses high, of 12-in. square timbers. The top tier to be 43 ft. wide, having eight courses of 12-in. square timbers. The cross-section of the

masonry, as shown by Fig. 2, was to be built on top of the last tier, with its base below low-water level. The face stones were to be 10 ft.



CROSS-SECTION
PROPOSED TYPE OF BREAKWATER
FOR AN OUTER HARBOR
FOR BUFFALO, N.Y.
Fig. 2.

long, 5 ft. wide and 2 ft. thick, laid alternately as headers and stretchers. The cost of 100 lin. ft. of this proposed structure was estimated as follows:

First tier of cribs	$3 440.60
Second " " "	2 984.60
Third " " "	2 536.94
Masonry	13 265.00
	$22 227.14
Contingencies, 10%	2 222.70
Total cost for 100 lin. ft	$24 449.84

This project was never carried out.

Meanwhile, the City dredged Buffalo Creek for an interior harbor, and, in 1848, extended its area by digging the Blackwell Ship Canal, 200 ft. wide and 16 ft. deep.

In June, 1867, General T. J. Cram submitted a project for the enlargement and repair of the harbor. This was modified in December, 1867, and in 1868 the modification was referred to a Board of Engineers, which recommended certain repairs to the piers at the mouth of Buffalo Creek and the deepening of the channel between them, which work was duly executed. They also proposed the shortening of the Erie Basin breakwater, and the construction of a canal from Buffalo Creek to the lake, about 1½ miles south of the south pier. These two items were rejected. However, the most important recommendation of this board was the project for a detached breakwater in about 27 ft. of water, beginning at a point in the prolongation of the south pier and 2 500 ft. from the lighthouse, thence running southward on a line parallel with the shore for 4 000 ft. See project marked *G* on Plate LVIII. The structure was to be of cribwork filled with stone and decked with plank; to have a rectangular cross-section; the width in 29½ ft. of water to be 34 ft., and in no case to be less than the total height from the bed of the lake to the top of the deck; and the top to be 5 ft. above the highest water known.

In accordance with this recommendation, the construction was duly authorized, and the contract for the northern end let to Messrs. Bailey and Denny. The first crib was sunk on June 7th, 1869, from which date begins the creation of Buffalo's outer harbor.

A Board of Engineers, convened in 1873 and 1874, recommended the construction of a sand-catch pier, to be formed of a pile pier, 10 ft. wide, covered by 6 ft. of superstructure, and extending to the 12-ft. contour in the lake, thence prolonged in the same direction to a total length of 1 270 ft. by cribwork, 20 ft. wide, having a superstructure 6 ft. high, the shore end of the pile pier to be connected with the railroad bulkhead behind it, by a close row of piles. This pier was to begin at a point opposite the south end of the City Ship Canal.

The Board also recommended that the detached breakwater be lengthened 3 600 ft., thus giving it a total length of 7 600 ft., instead of 4 000 ft., as adopted by the project of 1867. A shore arm was added,

built so as to leave a fair-weather opening of 150 ft. between it and the main structure, and to have a direction of 45° with the shore line until it reached the sand-catch pier, prolonged to meet it. See project marked *H*, on Plate LVIII.

The sand-catch pier was to serve the double purpose of arresting the movement of sand along the shore (a movement tending to shoal the entrance of Buffalo Creek), and also to close the south end of the new harbor, thus making, with the completed breakwater, a basin with a smooth anchorage ground of 300 acres outside the 16-ft. contour. The sand-catch pier was begun in the fall of 1874, and was completed in 1897, having reached a length of 1 148 ft.

The shore-arm breakwater, authorized in 1874, and, in connection with the sand-catch pier, intended to form the southern boundary of the proposed harbor, was begun in 1893. Of the 1 150 ft. under construction, 800 ft. had practically been completed, when, on October 14th and 15th, a severe storm from the southwest wrecked the entire structure. For more than 24 hours during this storm the wind velocity was greater than 40 miles per hour, reaching a maximum of 60 miles.

Up to this date, the various approved projects for a harbor, with their modifications, may be summarized as follows: The two piers at the mouth of Buffalo Creek, the north pier, 775 ft. long, and the south pier 1 475 ft.; a masonry sea-wall 5 720 ft. long, running southeast from the south pier, a detached breakwater, 7 600 ft. long, parallel to and about one-half mile from the shore; a sand-catch pier, 1 148 ft. long, and a shore arm, of a proposed length of about 3 000 ft., to close the south end of the space between the breakwater and the shore.

The wrecking of the shore arm directed attention toward an increase in the harbor area. In 1894 the extension of the breakwater to Stony Point received considerable public attention. On July 1st, 1895, a Board of Engineers submitted a plan for this extension, the essential features of which were: The construction of five isolated breakwaters, three to be each 2 900 ft. long, one of 2 400 ft., and a shore arm of 400 ft., a total of 11 500 ft. They were to be separated by openings about 350 ft. wide. The structure recommended was a rubble mound resting upon an artificial foundation to be secured by a trench excavated to bed-rock, and refilled with gravel to the lake bottom. On this foundation it was proposed to build a structure of small rip-

rap to a height of about 12 ft. below mean lake level, and upon this to build with large stone, weighing from 4 to 10 tons, up to about 10 ft. above that level. The large stones were to be deposited irregularly in a wall along the axial line of the proposed structure and with such side slopes as could conveniently be made to stand. It was expected that the action of the waves would reduce the height and flatten the slopes down to a position of ultimate stability. The cost of the proposed improvement was estimated at $2 200 000. See project marked *I* on Plate LVIII. See also Fig. 11, page 989.

The project of the Board of Engineers was reviewed critically by Major T. W. Symons, who assumed charge of the Buffalo District on October 14th, 1895, and who modified the plans materially. The changes made were the building of two breakwaters in place of five, with only one opening of 600 ft. between them. See project marked *J*, *K*, *L*, on Plate LVIII.

The breakwater was also located farther seaward, thus adding a considerable area to the harbor. The main breakwater was to have a length of 9 700 ft.; 5 000 ft. to consist of the rubble-mound type, and the remaining 4 700 ft. to be timber cribwork filled with stone, on an artificial foundation, obtained by excavating a trench and refilling it with sand and gravel. The other breakwater was to jut out from the shore at Stony Point 2 800 ft., and consist of timber cribwork founded in a manner similar to the main section. See Figs. 12 and 13, page 989.

The work was duly authorized by the River and Harbor Act of June 3d, 1896. The contract was let to Messrs. Hughes Brothers and Bangs, of Syracuse, N. Y., on January 27th and 28th, 1897, for $1 765 450.63.

The most northerly government breakwater at Buffalo is called the North Breakwater, and is a structure 2 200 ft. long, covering and protecting the entrance to Erie Basin and Black Rock Harbor and the lake front between the New York State structures known as the Erie Basin Breakwater and the Bird Island Pier. Its construction was authorized by the River and Harbor Act of March 3d, 1899. See project marked *M* on Plate LVIII.

The "Old" Breakwater.

The location of this structure, now locally known as the Old Breakwater is shown on Plate LVIII. Its northern extremity is a

point almost due west 2 500 ft. from the lighthouse on the west end of the South pier. It extends thence southeast for 7 609 ft., parallel with and about 2 900 ft. from the shore, and in water ranging from 22 to 30 ft. in depth. As it now stands, it consists of a substructure, of separate timber cribs filled with stone, of a uniform length of 50 ft., with their tops sunk approximately to mean lake level.

At the northern end, for 2 926 ft., the cribs are 34 ft. wide; this is followed by a section of 1 968 ft., in which the cribs are 38 ft. wide, and those of the remaining section, 2 715 ft. long, at the southern end, are 36 ft. wide.

This entire substructure was originally surmounted by a continuous superstructure of timber cribwork filled with stone, and of the same width as the substructure. In the beginning, this superstructure was only 8 ft. high, but later, a 4-ft. parapet, 12 ft. wide, was added on the lake side.

The construction was begun on June 7th, 1869, when the first crib was sunk. The last one was placed in 1893, the timber crib superstructure being finished on October 13th, more than twenty-four years having been occupied in the original construction.

Owing to the long period occupied in the building, it became necessary, long before the completion of the project, to make extensive repairs to the superstructure, due to the natural decay of the timber, and its consequent destruction by storms. For this reason the present superstructure consists of three types: A continuous timber cribwork filled with stone, a concrete monolithic structure, and a concrete-shell structure filled with rubble.

Many of the early harbors on Lakes Erie and Ontario were formed, as at Buffalo, by the building of parallel jetties, or piers, at the mouths of the larger streams, dependence being placed on floods to scour out the contracted channel between them. Later, as the draft of vessels increased, of course, sufficient depth of water had to be secured by dredging.

The favorite construction used in these works was timber cribs filled with stone. This method had many points in its favor, among which may be mentioned, especially, ease of construction and cheapness, and, in the case of the work under water, comparative permanency.

Regarding structures of this class, the following instructions formulated by the Board of Engineers, and of which Lieutenant-Col-

onel James Kearney, Corps of Topographical Engineers, was President, in charge of Lake Harbors and Western Rivers, on April 27th, 1853, are of interest:

"The Board having under consideration the principles of construction to be employed in building the piers, jetties and breakwaters on the Lakes, are of opinion:

"*First.*—That these works ought to be founded on cribs of timber filled in with stones.

"*Second.*—That the ordinary length of each crib should be 30 to 50 ft.

"*Third.*—That the breadth of the piers, etc., ought not to be less than 20 ft., even in the shoalest water.

"*Fourth.*—That their average width ought at least to equal their total height from the foundation to the platform.

"*Fifth.*—That the platform or deck of the piers, etc., ought to rise 5 ft above high-water level of the lake.

"*Sixth.*—That the side exposed to the waves ought to be vertical from top to bottom; and, as much as possible, free from angular projections or breaks.

"*Seventh.*—That the sheltered side ought to be vertical from the platform to 5 or 6 ft. below the low-water level, and thence downward it ought to have a slope or batter in grades of one-third to the natural foundation.

"*Eighth.*—That the timbers used in the work should be all squared or sawed.

"*Ninth.*—That the exposed face of the work ought to be covered with plank, well fitted and bolted to the timbers, and to extend if possible from the top to the natural foundation.

"*Tenth.*—That whenever it is dangerously exposed to floating ice, it should be defended by wrought-iron bars or straps well bolted to the timbers.

"*Eleventh.*—That the bottom of the cribs ought to be of grillage, the openings in which should be barely sufficient to allow the stone filling of the cribs to settle to the ground.

"*Twelfth.*—That the rip-rapping, if any, around the bottom of the cribs, ought not to rise so high as to be exposed sensibly to the waves.

"*Thirteenth.*—That the piles, which are used sometimes in the inside of the cribs, have not the effect to keep them permanently in place or plumb.

"*Fourteenth.*—That the cribs beneath the water surface should be of the same width as the piers or breakwaters, and may be of different lengths. Above water the cribwork should be constructed so as to preserve a break-joint connection throughout the whole length of the work.

"*Fifteenth.*—That due time having been allowed for the ultimate settlement of the structure; the upper part of it should be replaced by masonry, namely, from a point so low that the timbers of the foundation may not be liable to come in contact with the atmosphere.

"The Board reserves for a future report the question of the dimensions of the timbers, the method of framing, or the carpentry, of the cribs, the filling in with stone, and the setting of the cribs into place.

"To enable the Board to arrive at satisfactory opinions upon points now referred to, and enter into the details which ought to characterize such a report, it will be necessary for the members to examine for themselves the works most worthy of notice, or those that are thought to be the most successful examples of cribwork on the Lakes, as well as those that are defective.

"The Board would thus be enabled to judge more satisfactorily as to the causes (arising either from inherent defects or accidents) that led to their failure; and, on the other hand, the causes that may have contributed to the efficiency of those that have succeeded."

When, in 1867, General Cram submitted a project for building a detached breakwater, which was to form an outer harbor, there was, as a matter of course, some discussion of the proposed plans, especially as to the proper cross-section of the cribs, and of their details.

The matter was referred to a Board of Engineers, convened in 1868, which recommended that the structure be built of cribwork filled with stone and decked over with plank, to have a rectangular cross-section; the width in 29½ ft. of water to be 34 ft , and in no case less than the total height from the bed of the lake to the top of the deck, and the top to be 5 ft. above the highest water known.

The location of the work and the construction details having been decided, the contract for the northern end was let to Messrs. Bailey and Denny in 1868.

The cribs were 34 x 50 ft., and 23 ft. deep, which was also the depth of the water, the cribs being set directly upon the natural bottom, without any preparation. With the exception of the top courses, which were pine, the cribs were of 12-in. square hemlock, duly framed, and fastened with 1¼-in. square iron drift-bolts 45 ins. long. Each crib contained about 110 000 ft., B. M., of timber, 11 tons of iron, and 280 cords of stone. The superstructure was of pine, and was built 8 ft. above the water level.

As the lake bottom of the area adjacent to the north end of the breakwater is generally rocky, overlaid with a thin layer of sand, no apprehension seems to have been felt in placing the cribs directly

thereon; in fact, it is doubtful if any extended examination of the bottom, along the line of the proposed work, was made or considered necessary at the time.

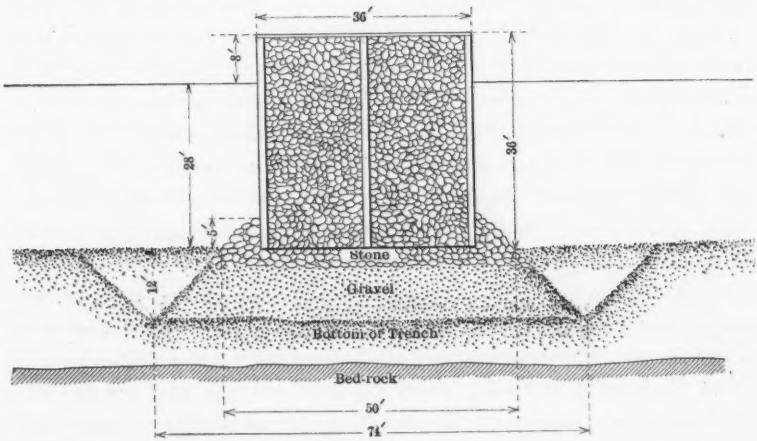
During the summer of 1872 a change in the character of the lake bottom was noticed. The hard gravel bottom became thinner and an underlying stratum of soft clay came near the surface. Much difficulty was found in keeping in position cribs sunk upon this yielding foundation. They sank as much as 4 ft. in 24 hours. In the following winter the cribs sank as much as 8 ft., the settlement being very uneven. The cribs were also displaced sideways to a greater or less extent, varying from 4 to 24 ft., but their integrity did not seem to be disturbed. The damage was repaired by sinking on top of the disorganized work a repair crib of irregular shape, from 4 to 24 ft. wide, 19 to 6 ft. high, and 315 ft. long. This was fastened to the old cribs by two iron rods, running through from side to side, and by piles driven in the corners to bed-rock.

In 1873 the mode of construction was changed. An artificial foundation was made by spreading over the lake bottom a layer of rubble, which, by its weight, settled into the soft clay. It was raised about 4 ft. above the lake bottom, and extended 25 ft. exterior to the lake face of the cribs, and 15 ft. on the harbor side. On this foundation two cribs were placed, each 34 x 50 ft. and 22 ft. deep. A superstructure was built over them and the displaced work of the preceding year.

On December 4th, 1873, a gale displaced these two cribs, wrecked 150 ft. of superstructure and damaged all the superstructure built in 1872–73. The 315 ft. of 1872 settled still more, and with great irregularity. The prepared foundation of broken stone sank through the soft clay so completely as hardly to be found by sounding. It was very evident that the prolongation of the line of that part of the breakwater already completed passed through an area of soft bottom which offered great difficulties in foundation.

Under the direction of Mr. (now Dr.) George E. Fell, the bed of the lake along the line of the extension was examined by drivings made from a scow provided with special machinery, and was found to consist in great part of a soft blue clay, into which the cribs might be expected to settle considerably. To prevent this settlement, a Board of Engineers, convened in the spring and again in the fall of 1874,

recommended an artificial foundation, to be made by dredging a cut in the bottom of the lake on the prolongation of the line of the breakwater, making this cut 50 ft. wide at the bottom, carrying it down to bed-rock, unless sufficiently firm clay, sand or gravel were found at a less depth; the side slopes of the cut to be as steep as the material would stand, and the cut, as fast as made, to be filled with gravel to the level of 3 ft. below the mud bottom, which level was to be reached by a covering of 3 ft. of rubble, having a width of 50 ft. at top. The Board supposed that this foundation would only be necessary for about 2 500 ft. from the terminus of the completed work, and for that distance estimated the average depth of dredging at 12 ft., at a cost not to exceed $150 000 (see Fig. 3). The Board also recommended that the



CROSS-SECTION OF PROPOSED
BREAKWATER EXTENSION
SHOWING
TRENCH AND FILLING FOR FOUNDATION

Scale of feet

10 5 0 10 20 30 40 50

FIG. 3.

length of the breakwater be increased 3 600 ft., making its ultimate length 7 600 feet, this to make a large still-water harbor, as well as to cover a long shore line which would be available for docks.

The work of excavating this trench was commenced during the summer of 1875. At the beginning the depth of soft clay excavated was from 8 to 10 ft., but in 1878–79 it increased to from 19 to 22 ft.,

which delayed the work, the water being about 30 ft. and the bottom of the trench therefore about 49 to 52 ft. deep. Later, the depth decreased, and in 1882 this stratum pinched out entirely. Borings taken southward from this point for 1 500 ft. indicated that the bottom was composed of boulders and gravel, and gravel mixed with hard clay. It is stated that a pointed rod could not be driven into this material more than 4 ft., therefore there was no further apprehension as to future settlement.

The length of unstable foundation which required dredging and back-filling with gravel was about 2 500 ft. It underlies that portion of the breakwater built between 1874 and 1882.

As previously stated, the height of the superstructure, as originally constructed, was only 8 ft. above lake level. The length of this type of structure was 4 891 ft. It is a well-known fact that in heavy gales from the west Lake Erie rises 5 or 6 ft. and more, above ordinary low water, which would leave only 2 to 3 ft. of the breakwater above the surface. The effect of this high water is to create a heavy sea inside the breakwater. A gale of this kind occurred on January 3d and 4th, 1884, which did great damage to the superstructure for 800 ft. southward from a point 2 000 ft. from the north end, and a large part had to be rebuilt. To remedy the disturbance caused by the high seas, a parapet, 6 ft. high and 12 ft. wide, was added in the reconstruction, and all the work (2 718 ft.) constructed after 1884 was built after this plan, except with occasional and slight modifications as to height.

In the timber cribwork, generally, hemlock was used for the under-water work, except for the few top courses, between "wind and water," where pine (and, in a few cases, oak) was substituted. The superstructure was of pine, with the exception of the stringers, which were usually oak. The sides and ends of the cribs are of 12 x 12-in. timbers, built up solid. The interior cross- and longitudinal- ties are of the same dimensions, and are laid in "cob-house" style. At first, all timbers were fastened with square iron drift-bolts; later, round iron was substituted. The later cribs were built of two parts. The lower was a grillage, the timbers of which were fastened with screw-bolts. In the work above the grillage, drift-bolts were used. The superstructure is similar in design, except that, usually, the interior ties are laid close, forming solid bulkheads. The decking, of 3-in. plank, is laid at right angles to the axis of the work.

The work was paid for at unit prices for the various classes of material. In the beginning, a price was paid for the timber, and another price for framing. It was also the practice, at times, to let the cribwork and the bolts and spikes separately.

One prominent feature of some of the cribwork of the old breakwater was the abnormal length of some of the timbers used. In the grillage, not less than thirteen pieces of timber, each 50 ft. long, were used. In the hemlock portion of the cribs there was an extremely large number of 36-ft. pieces, aggregating nearly 70% of the total timber. This was on account of making the end walls and cross-ties in one piece. In the top part of the cribs and in the superstructure more than 30% of 36-ft. pine timbers and about 65% of oak timbers were used.

No figures, giving the total cost of the original timber-crib breakwater, are available. The Board of Engineers which determined the plans of this breakwater (March 27th, 1868), estimated the cost of a 100-ft. section, with cribs 34 x 50 ft., but depth not given, as in Table No. 1.

TABLE No. 1.—Estimated Cost of 100-Foot Section of Timber-Crib Breakwater.

12-in. timber	11 406 cu. ft.	@ $0.24	$2 737.44
Plank	5 580 ft. B. M.	" 20.00	111.60
Square bolts	14 835 lbs.	" 0.03⅞	555.58
Spikes	350 lbs.	" 0.05½	19.25
Rubble	1 750 cu. yds.	" 1.50	2 625.00
Framing	11 871 cu. ft.	" 0.12	1 424.52
Contingencies	10%		747.40
Total cost of 50-ft. crib			$8 220.79
" " " 100-ft. "			$16 441.58

In 1873, the theoretical cost (with no allowances for settling or contingencies) of 50 ft. of breakwater was estimated as in Table No. 2.

TABLE No. 2.—Theoretical Cost of Breakwater.

Timber and lumber	139 875 ft. B. M.	@ $20.00	$2 797.50
Framing	11 891 lin. ft.	" 0.12	1 426.92
Joist and plank, fitting, etc	2 876 ft. B. M.	" 7.00	20.13
Drift-bolts	32 197 lbs.	" 0.03⅞	1 247.63
Spikes	680 lbs.	" 0.05½	37.40
Stone	435 cords.	" 6.85	2 979.75
Total			$8 509.33
Cost per linear foot			170.00

TABLE No. 3.—Cost of Timber-Crib Breakwater, per Linear Foot, for Different Years.

Length, in feet.	Contractor.	Date.	Cribs.	Distance from North end, in feet.	Cost.	Cost per linear foot.
150	Ambrose Clark	July 25, 1877 September 30, 1878	Three, 50 x 38 x 30 ft.	3 076		$160.00
353	Franklin B. Colton	October 29, 1878 August 31, 1879	Seven, 50 x 38 ft.	3 429		184.00
504	D. E. Bailey	January 27, 1880 August, 1881		3 933	$104 259.31	206.86
504	D. E. Bailey	September 25, 1880 November, 1881	Ten, 50 x 38 ft.	4 437	104 225.78	206.80
454	Hingston and Woods	May 27, 1881 November, 1882	Nine, 50 x 38 x 28 ft.	4 891		160.00
805.9	Charles E. Williams	February 21, 1884 October 29, 1884	Sixteen, 50 x 36 x 24 x 22 ft.	5 696.9	89 783.58	111.40
652.9	Ira Farnsworth	October 4, 1884 October 10, 1885	Four Five	6 349.8	64 173.44	98.29
452.6	J. B. Donnelly	April 17, 1891 November 9, 1891	Nine, 50 x 36 x 22 ft.	6 802.4	60 189.91	132.99
806.3	J. J. Churchyard	October 13, 1893		6 808.7		

Table No. 3 shows the cost of the timber-crib breakwater per linear foot, for different years. In this table it will be noted that there is quite a variation in cost. The low cost for 1877–78 was owing to the fall in prices of material and labor. In 1879–80–81, the depth of soft clay, excavated for the foundation, and refilling with gravel, was greater than under any other contract, hence the increased cost. In 1884 and afterward no trench excavation or backfilling was necessary, the natural bottom of the lake being hard enough to sustain the work. The rates in Table No. 3 include all expenses of every kind, the net cost of the workmanship being 6 to 10% less than those rates, according to the amount done.

As a rough guess, it may be stated that the total cost of the breakwater was, approximately, $1 500 000.

Concrete Superstructure.—Great damage was done to the structure by the gale of October 14th, 1886, the heaviest experienced since November 16th, 1869. The wind was from the southwest, and reached, at one time, a velocity of 70 miles an hour. The level of the lake was raised 7.3 ft. above standard low water. For a length of 1 910 ft., beginning at the north end, almost the entire harbor face of the breakwater was pushed out of place. The ends of the cross-ties had become so rotten that in many cases the wood of the dovetails stripped off. The ice of the following winter also did more or less damage, especially to the cross-walls or bulkheads of the parapet (first built in 1884), which were partly laid up "cob-house" fashion, the ice being piled up 30 ft., or more, in height. In many places, the lake face of the breakwater was also crushed in by the ice. The dilapidated condition in which the north end of the breakwater was left after this storm, made it evident that the reconstruction of the superstructure was an absolute necessity. On December 15th, 1886, a plan for a new superstructure, of concrete, faced with stone, was submitted by Captain F. A. Mahan. Some changes in the same were made, it being ordered to build 500 ft. with stone facing and 250 ft. with a facing of Portland-cement concrete, the work to be done by day's labor and the materials to be obtained under contract.

The approved plan, as finally adopted, was as follows:

1.—The timber cribs of the foundation were to be cut down to 2 ft. below mean low water;

2.—On the razed cribs was to be built a masonry foundation, 5 ft.

high, of the same width as the cribs, vertical on the harbor side and with a slope of 5 on 3 on the lake side;

3.—On this structure was to be built a parapet 20 ft. wide at the bottom, 17 ft. wide at the top, and 9 ft. high, the slopes of both the harbor and lake sides being 6 on 1; the lower edge of the lake side of the parapet to coincide with the upper edge of the lake side of the foundation.

The new superstructure was to be built in two ways:

1.—The inside mass of natural-cement concrete to be covered with stone masonry of varying thickness; on the lake face, 3 ft.; on top, 2 ft. for 5 ft. back from the lake face; the remainder of the top, 1 ft.; the harbor face of the foundation, 2.5 ft.; the top face of the foundation, for a width of 11.5 ft., to be uncovered.

2.—The concrete mass was to be covered on all sides with a layer of Portland-cement concrete, 3 ft. thick.

The work was commenced, about June, 1887, by tearing out the timber superstructure and preparing the tops of the cribs to receive the concrete.

The laying of the concrete was begun on July 30th, 1887, and closed for the season on November 14th. After August 11th, work was prosecuted night and day, and, after September 4th, also on Sundays. See Figs. 4 and 5.

Details of Construction.—The plant consisted of a derrick scow 92½ x 20 ft., drawing 2 ft. when loaded. The derrick was fitted with a long boom for light loads and a short one for heavy loads. It was operated by a single-cylinder double-drum engine. Near the stem there was a small blacksmith shop. There were also three scows, each 95½ x 17 ft., and drawing 5 ft. when loaded. One scow was fitted with a concrete mixer at one end, the mixer being a 4-ft. hollow cube of boiler iron, driven by a single-cylinder engine. At the other end there was a platform on which the cement paste was mixed. A track connected this platform with the mixer. There was also another scow, 55½ x 20 ft., drawing 3¾ ft., which, with two of the larger ones, was used for the transportation of material. A small derrick scow was used by the stone masons, and a large flat scow, of about 300 tons capacity, was used for the storage of sand and gravel.

The tools were of the usual kinds. The rammers were of cast iron, with wrought-iron handles. The base was 5 ins. on an edge at

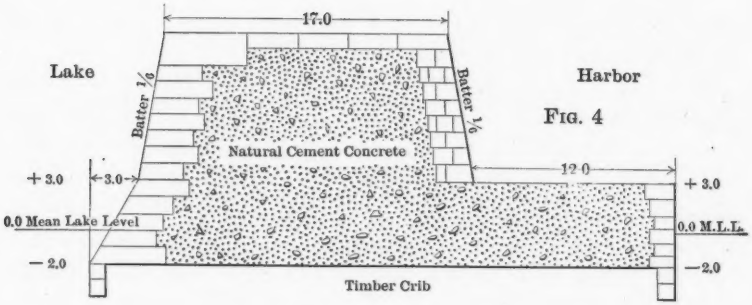


FIG. 4

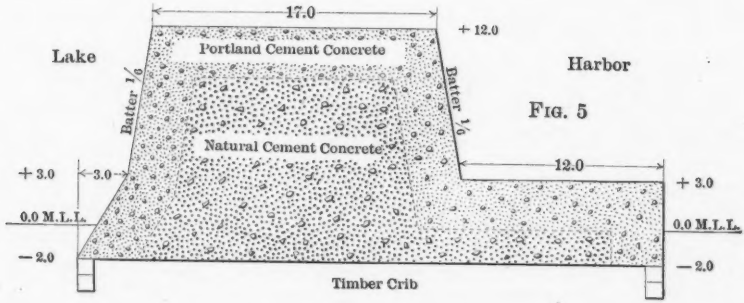


FIG. 5

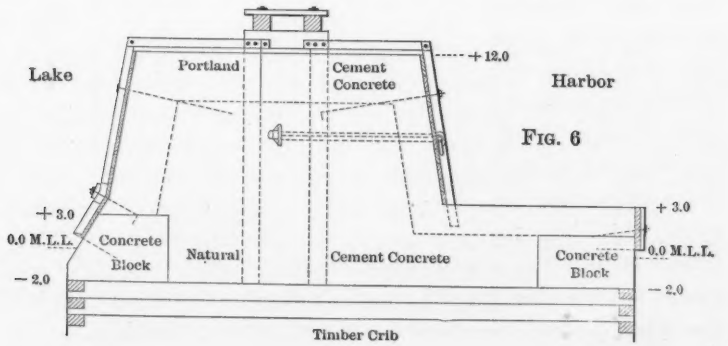


FIG. 6

the bottom, 3 ins. at the top, and 6 ins. high. The wheel-barrows carried boxes holding 2 cu. ft. each.

The concrete forms were of wood, with 4 x 6-in. posts or braces, attached to the cribwork timbers by wrought-iron knees. The sheeting was of 2-in. plank spiked to the posts.

Execution of the Work.—The derrick boat was placed broadside along the harbor face of the breakwater. In front of this boat, and head on, lay the mixer boat, and immediately in the rear was the large float loaded with sand and pebbles. On one side of this float was placed the emergency stone scow, and on the other side the contractor's stone scow. When the boats were all in position, runways were laid from the mixer scow to the various vessels, so that the materials could be wheeled up conveniently. The arrangement of the scows is shown in Fig. 7.

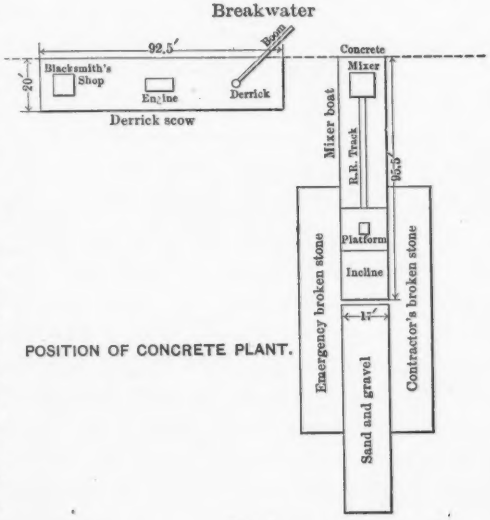


FIG. 7.

The concrete was made as follows: The cement (2 cu. ft.) was mixed into a rough paste on the platform. The other ingredients, in the proper proportions, were then wheeled to the platform and dumped through a hole in the same into a large box standing on a railroad truck beneath, in the following order: First the pebbles, then the sand, and then the broken stone. The cement paste was thrown in with the sand. The loaded box was then run out, raised by the derrick, and dumped into the mixer, the box was returned and the operation repeated.

After from five to ten revolutions of the mixer, the concrete was emptied into another box, and placed in the work by the derrick. It was then spread in layers of 6 to 8 ins. and rammed thoroughly.

With full gangs, fourteen batches per hour could be placed. The average for the entire season was about seven batches per hour. With

the larger number of batches, twelve men were required for ramming alone.

The construction of the stone face was very simple, and differed in no respect from the ordinary methods of constructing masonry.

Difficulties Encountered.—The greatest difficulty was caused by the instability of the boat. The management of the boxes of concrete was exceedingly troublesome. Comparatively small oscillations of the boat amplified greatly the movement at the end of the boom. Difficulty was also found in placing the concrete at the salient angles at the bottom of the structure. It was washed out by the swell caused by passing boats, or by the wind, and the angles then crumbled. Every way that the ingenuity of the force could devise was adopted to try to prevent this wash until the cement could set. Not one was successful. The best results were obtained by the use of tarred paper and crash, with which the effect of the wash was less than by any other method.

The weather, as a rule, was favorable, with the exception of two gales, which did some damage, washing out some of the interior concrete. All the work was done by hired labor, the plant being owned by the United States Government.

Cost of the Work.—The Portland cement used was the "Gibbs," from London, England. The contract price was $2.09 per barrel, delivered in Buffalo by canal. A little came by rail, which made the average price 2.16\frac{8}{10}$. Some additional cement needed cost $2.57 per barrel.

The natural cement was furnished by F. O. Norton, of New York, at $1.20 per barrel, delivered in Buffalo by canal. Sand cost 80 cents per cubic yard, and pebbles $2 per cubic yard. Broken stone, furnished by contract, cost $1.84 per cubic yard. Owing to the inability of the contractors to supply broken stone promptly at all times, some was broken by hired labor at a cost of 3.25\frac{3}{4}$ per cubic yard.

The cost given has reference to the work as it stood on April 1st, 1888, being practically that done during the season of 1887.

The quantity of concrete made was as follows:

Portland-cement concrete	2 937.71	cu. yds.
Natural-cement concrete	2 149.58	" "
Total	5 087.29	" "
Less large stone in same	300.00	" "
Net quantity of concrete	4 787.29	" "

This quantity was made in 5 797 batches, giving 0.8258 cu. yd. to the batch. The quantities required to make a cubic yard of concrete are shown in Table No. 4.

TABLE No. 4.

	Concrete.	
	Portland cement.	Natural cement.
Cement, cubic feet	3.288	2.411
Sand, " "	5.021	5.021
Pebbles, " "	14.805	14.805
Broken stone, cubic feet	14.473	14.473
Total	37.587	36.710

In the statement of cost in Table No. 5 the items of material and labor only are included:

TABLE No. 5.

				Concrete.	
				Portland cement.	Natural cement.
Portland cement	2 383	bbls. at	$2.168 =	$5 166.34	.....
" "	193	"	2.57 =	496.01	.....
Natural "	1 383	"	1.20 =	.....	$1 659.60
Sand	946	cu. yds. at	0.80 =	437.02	319.78
Pebbles	2 789.6	"	2.00 =	3 221.77	2 357.43
Broken stone	1 778	"	1.84 =	1 841.20	1 347.24
" "	949	"	3.25¾ =	1 785.10	1 306.19
Labor				6 952.43	5 087.22
Total				$19 899.87	$12 077.46
Cubic yards in place				2 937.71	2 149.58
Cost per cubic yard				$6.774	$5.62

The cost of the 250-ft. section was $73.39 per running foot.

Owing to the excessive cost of the masonry-faced section (200 ft. long) it was recommended that this method of construction be discontinued.

Concrete Blocks.—As it was almost impossible to preserve the integrity of the angles at the bottom of the profile when building the concrete in place, authority was given, in February, 1888, to use large concrete blocks at the bottom of the work. The blocks for the lake face were 6 ft. long on the bottom, 4 ft. 2 ins. wide, and 4 ft. high, and were set as headers, the end toward the lake rising vertically for 1 ft.

and then having a batter of 5 vertical to 3 base, the opposite end being vertical. The blocks on the harbor face were rectangular parallelopipedons, 6 ft. long, 4 ft. 2 ins. wide, 3 ft. 6½ ins. high, and contained the same volume as the blocks on the lake face, namely, 88.75 cu. ft. or 3.287 cu. yds. See Fig. 6, page 967; also Fig. 9, page 976.

The first block was made on August 6th, 1888, and at the close of actual operations, on November 28th, 1888, 625 had been made; of these four were damaged so as to be useless. The blocks were made in wooden moulds, the grooves for the reception of the hoisting chains being formed by battens. Forty-two of these moulds were made, costing $1 675.99, or $39.90½ each.

The blocks were made on the south pier, behind the parapets of the old breakwater. The concrete was hand-mixed in the following proportions: ½ bbl. of Portland cement, 2½ cu. ft. of sand, 7½ cu. ft. of pebbles, 7½ cu. ft. of broken stone.

These quantities made a layer of concrete a trifle more than 6 ins. thick. The face of the lake-face blocks was made of rather finer materials than the inside. This finer concrete was about 6 ins. thick, 6 to 8 ins. wide, and well rammed. The coarser concrete was spread just behind it, before the face had set, and, being properly rammed, gave a thorough bond between the face and the back. The block was built up in this way in successive layers. In the top layer irregular masses of stone were set so as to project 6 or 8 ins. above the top of the block when finished. These stones served as dowels to insure a firm bond with the superstructure. One gang of men, on several occasions, made fourteen blocks in 10½ hours. This, at 3.287 cu. yds. to the block, gives 46 cu. yds. per day, or 4.37 cu. yds. per hour.

The total volume of the blocks is 2 054.37 cu. yds. The materials used were:

Sand	364.55 cu. yds.
Pebbles	1 175.10 " "
Broken stone	972.22 " "
Cement	258.09 " "
Total volume of loose materials	2 769.96 " "
Total volume of blocks	2 054.37 " "
Shrinkage	715.59 " "

or 25.8 per cent.

The disparity in sand and other materials was caused by many of the blocks requiring to be placed on a special bed while under construction. The excess of pebbles over broken stone was caused by using the finer material for the lake face, so as to expose a smoother and more solid surface to the waves.

The cost of the materials for the blocks was:

Cement	$4 464.98	
Sand	291.64	
Broken stone	1 701.39	
Pebbles	2 350.20	
		$8 808.21
Superintendence	$476.04	
Labor	3 908.55	
		4 384.59
Tools, supplies, tug hire, boats, repairs, etc		4 085.04
Moulds		1 675.99
Total cost of making 625 blocks		$18 953.83

This gives, as the cost per block:

Materials	$14.093
Superintendence and labor	7.015
Miscellaneous	6.536
Moulds	2.682
Total cost of a block ready to set	$30.326

or $9.226 per cubic yard.

The following prices were paid for the materials:

Portland cement	$2.45	per barrel.
Sand	0.80	per cubic yard.
Pebbles	2.00	" " "
Broken stone	1.75	" " "

The handling and setting of the blocks was very simple, and was accomplished by a floating derrick, lashed alongside of which was a scow, connected by 12-in. timbers to steady it. This made a very stable arrangement.

In the cost of setting the blocks is included the cost of recovering

(by means of a diver) 349 blocks which were washed overboard by severe gales. Of these, twenty-four were damaged so much that they were unavailable for use in the faces of the structure, and had to be used in the interior.

Cost of making blocks	$18 953.83
Cost of setting blocks	4 239.84
Total cost of blocks	$23 193.67

This amount, apportioned among the 621 blocks actually used, makes the cost $37.35 each, or $11.29 per cubic yard.

The wages paid to the various artisans were as follows:

Master laborers	25, 27½ and 30 cents per hour.
Laborers	17½ and 20 " " "
Carpenters	25, 27½ and 30 " " "
Blacksmiths	17½ " " "
Enginemen	25 and 30 " " "

Tearing out the Old Timber Superstructure.—Various storms, beginning with that of October 14th, 1886, had done more or less damage to the old timber superstructure. In some places the harbor wall of timber had been carried away to the water's edge, and the stone in the pockets had been washed out. In other places the stone had been dug out of the pockets and the timber left standing. Nearly one-third of the timber had been torn off. To remove the timber which remained, various methods were tried, such as pulling up sticks by means of a derrick boat, sawing and splitting the timber away from the drift-bolts, pulling the drift-bolts with a heavy shackle bar, etc. The most satisfactory and expeditious method, however, was that of drawing the bolts partly with a hydraulic jack and finally with a shackle bar. By this method the timber was uninjured, except for the small cut made at each of the drift-bolts to allow the jack to take hold.

After the bolts were removed, the timbers were readily taken apart, and many of them were used for trestling, for scaffolding, and for stringers in connection with the railway track used in transporting the concrete to the work.

The cost of tearing out the old superstructure was as follows:

Superintendence	$287.07
Labor	5 110.34
Miscellaneous, including stone removed by contract, tools, tug hire, boats, etc	2 509.54
Total cost	$7 906.95

The length of the structure torn down was 1 460 ft., making the cost per linear foot 5.41\frac{6}{10}$.

Concrete in Place.—On account of the difficulties encountered during the season of 1887 in making and depositing concrete with a floating plant, the question of a different plant to be used in continuing the work (the construction of 1 460 ft. during 1889), was considered by a Board of Engineers in December, 1888. This Board recommended a traveling platform, designed to carry on a lower deck the mixer, boiler, engine, coal bins, cement, tools and other appliances, and, on an upper deck, the bins containing sand and broken stone.

The plan suggested was to set all the blocks, and fill in behind them with concrete to a depth of 2 or 4 ft., then, working backward, build up to a level of 7 ft., then, working forward, finish to the required height of 12 ft.

It was also contemplated to utilize, for the storage of materials and the making of concrete, that portion of the breakwater with which there had been trouble on account of settlement and displacement of the cribs, and which had a width of from 30 to 45 ft.

On January 9th and 10th, 1889, occurred the most furious wind storm known in Buffalo. From 4 A. M. until noon of January 10th the hourly velocity of the wind was never less than 61 miles. From 8 to 9 A. M. it averaged 78 miles. During this storm 346 of the concrete blocks, weighing about $7\frac{1}{2}$ tons each, which were lying on the banquettes of the breakwater and sheltered by the parapet, were washed overboard. As previously stated, much damage was done to the 1 460-ft. section upon which the concrete superstructure was to be built during the season of 1889.

After the effects of the storm were fully known, the Board of Engineers, in March, 1889, decided that, in view of the changed conditions, temporary fixed platforms would be more expeditious than the traveling platform previously recommended; also, that it would

PLATFORM FOR MIXING CONCRETE.

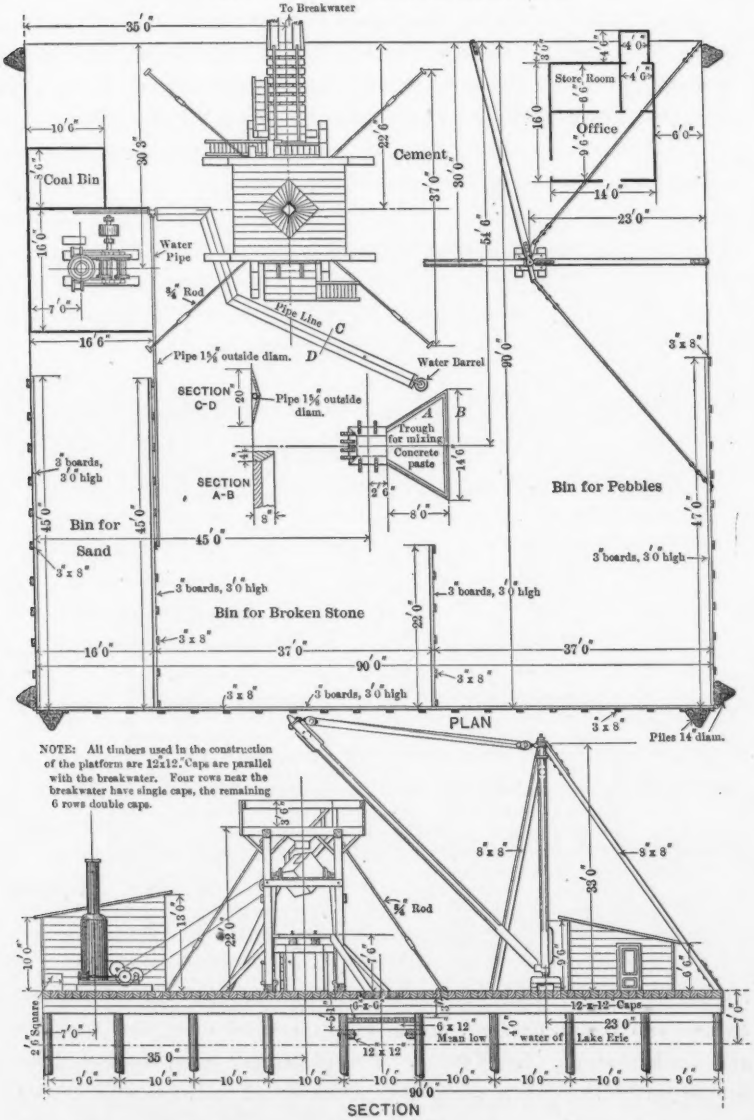


FIG. 8.

not be advisable to use the banquette deck of the breakwater for the storage of materials and machinery.

In accordance with this decision, two platforms, each 90 ft. square, were built close to the harbor side of the breakwater, one at the quarter point and the other at the three-quarter point of the work. They were constructed of piles, capped with 12 x 12-in. timbers and

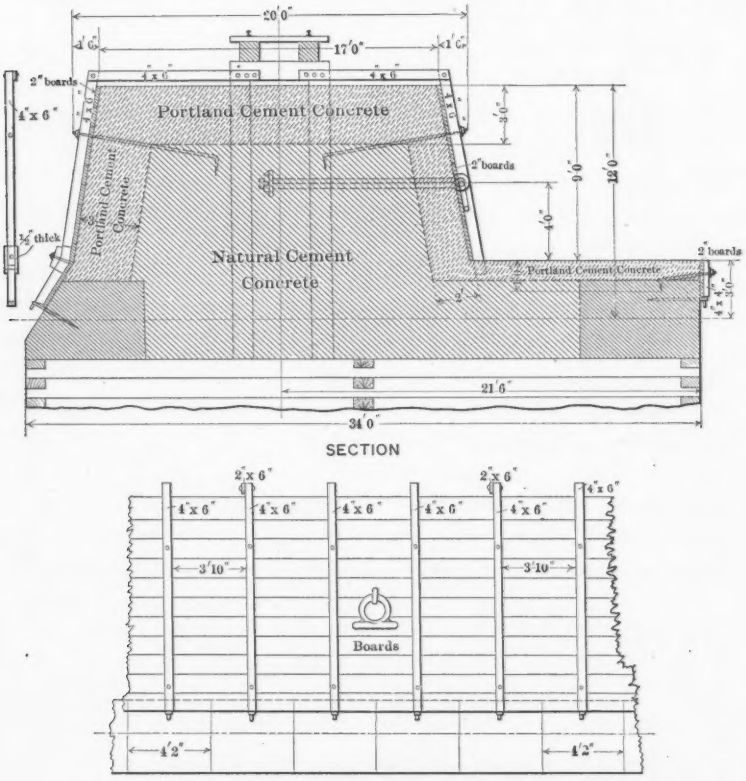


FIG. 9.

decked over. On these platforms were located the concrete mixer, engine and boiler, derrick, steam pump, and bins for sand, pebbles and broken stone. See Fig. 8. The platforms were connected by proper turnouts, with a temporary single-track railway, with trestle bents, 10 ft. apart, and running the entire length of the work. See Fig. 9, also Fig. 6.

The formula for the concrete was: 1 bbl. of cement, 5 cu. ft. of sand, 15 cu. ft. of pebbles, and 15 cu. ft. of broken stone.

To meet these requirements, hand carts of the capacity needed to carry the exact quantity of each sort of material were built. In addition, there were charging boxes, each of 40 cu. ft. capacity, and these were lowered to a sub-platform through a hole in the deck of the platform, their tops being level with the deck for convenience in charging. The cement was made into a rough paste in a special trough. In charging, the pebbles were dumped first, then the paste was shoveled in at the same time that the proportions of sand and broken stone were served. An additional quantity of water was poured in, and the charge hoisted to the mixer. From the mixer the concrete dropped into a car, which carried it to the work for deposit.

With these arrangements, the quantity of concrete from one mixer has been as much as 225 cu. yds. in 10½ hours.

The volume of the new superstructure is as follows:

Concrete blocks	1 962.34	cu. yds.
Masonry	228.00	" "
Large stones	679.30	" "
Damaged blocks	56.78	" "
Concrete in place	14 586.78	" "
Total	17 513.20	" "

The number of batches of concrete was 14 624, from which it is found that each batch, rammed in place, had a volume of a little less than a cubic yard.

The materials were mainly supplied by contract, at the following prices:

Portland cement	$2.45	per barrel.
Natural cement	0.82	" "
Sand	0.80	per cubic yard.
Pebbles	1.75	" " "
Broken stone	2.00	" " "

The Portland cement was made by Burham and Co., of England. The natural cement was made by the Union Akron Cement Co., in the

neighborhood of Buffalo. The sand came from the south shore of Lake Erie; the pebbles were brought from the Niagara River, near the International Bridge, and the broken stone came from Lockport.

There was also used in the work another English Portland cement, the Francis, at $2.45 per barrel, also Millen and Sons' domestic Portland, at $2.25, also some of F. O. Norton's natural cement, at $1.20.

One barrel of cement was used in each batch of concrete, and, as each batch made practically a cubic yard, the cost of the cement per cubic yard was the same as the price per barrel. The cost of the other materials in each batch was: Sand, 15 cents; pebbles, 97½ cents; broken stone, $1.11; a total of $2.23½.

Cost of the Concrete.—The elements of the cost of the concrete are, labor, material and miscellaneous expenses. Labor is divided into superintendence, or time of master workmen; and labor proper, or time of men acting under the guidance of the master workmen.

Superintendence	$1 426.41
Labor	20 851.73
Total	$22 278.14

The cost per cubic yard for superintendence and labor was $1.53. The largest labor item was the ramming, which was 25 per cent.

The cost of materials was:

Cement	$21 144.91	
Sand	2 193.60	
Pebbles	14 258.40	
Broken stone	16 232.64	
		$53 829.55
Material and labor for grouting and filling holes		274.82
" " " " large stone used in concrete		2 576.63
Masonry used instead of concrete blocks		5 587.40
Total		$62 268.40

The miscellaneous expenses were:

Cost of two platforms	$14 390.41
Derricks, machinery, pumps, rails, tug hire, etc.	29 647.53
Total	$44 037.94

The total cost of reconstructing 1 460 ft. of the superstructure of the breakwater was:

Tearing out old timber work		$7 906.95
Making and setting concrete blocks		23 193.67
Superstructure; concrete in place:		
Labor	$22 278.14	
Materials	53 829.55	
Extra work	8 438.85	
		84 546.54
Miscellaneous expenses		44 037.94
Total		$159 685.10

The cost was $109.37 per running foot, or $9.12 per cubic yard.

The value of the plant at the end of the season was taken to be $18 470. This, subtracted from the total, leaves $141 215.10; thus the net cost of the new superstructure was $96.72 per running foot, or $8.06 per cubic yard. The cost of the concrete in place, added to the cost of the platforms and the other miscellaneous items, gives:

Concrete in place (labor and material)	$76 382.51
Platforms	14 390.41
Miscellaneous	29 647.53
Total	$120 420.45
Deduct value of material and machinery on hand	18 470.00
Remainder	$101 950.45

Dividing this by 14 586.78, the cubic yards of concrete, gives $7.00 per cubic yard as the net cost of the concrete in place.

Sixty-eight days were required to place the concrete, thirty-eight days with one platform and thirty with two. This gives an average output of 214.51 cu. yds. per day.

After the decayed superstructure at the north end had been reconstructed, it was decided to replace another section, immediately south of that part which settled during 1872. This settled portion is known as the ice-breaker, and will be designated thus hereafter. The section adjoining the ice-breaker was to be 1 967.9 ft. long. During the season

of 1890, 950 large concrete blocks for the same were made. The River and Harbor Bill of September 19th, 1890, appropriated $200 000 for this work.

Before commencing the concrete superstructure, it was necessary to remove the old decayed timber superstructure, which was a work of no little magnitude, as it contained about 760 000 cu. ft. This work was commenced on April 9th, 1891, and by June 15th, 1891, the structure was about all removed to a plane 2 ft. below mean lake level. This removal necessitated the handling of 1 678 280 ft. of timber, 120 000 lbs. of iron, and 19 500 cu. yds. of stone. On June 8th, 1891, the setting of the concrete blocks was commenced, and at the end of the year (June 30th, 1891), 800 had been placed in position. The platforms on piles for storing material for concrete, one at either end of the work, and the concrete mixers were ready at about the same date. Trestlework had been erected along the line upon which the superstructure was to be built, and upon this two tracks were laid. The cars for carrying the concrete were moved by a wire cable operated by a steam engine.

On July 4th, 1891, a heavy gale washed from the breakwater 362 blocks, each weighing about 7 tons. The blocks were all recovered by a diver, the last one being raised on August 23d, 1891.

The laying of the concrete began on August 4th, and was practically finished on October 12th. An experimental top parapet, 300 ft. long and 5 ft. high, was begun on October 17th and finished on the 19th. All top dressing was finished on November 8th.

The machinery and method of construction have been described, and it only remains to note that a great volume of concrete was laid quickly and successfully, the cable road being a perfect success, and previous experience having led to skill and promptness in the details of construction.

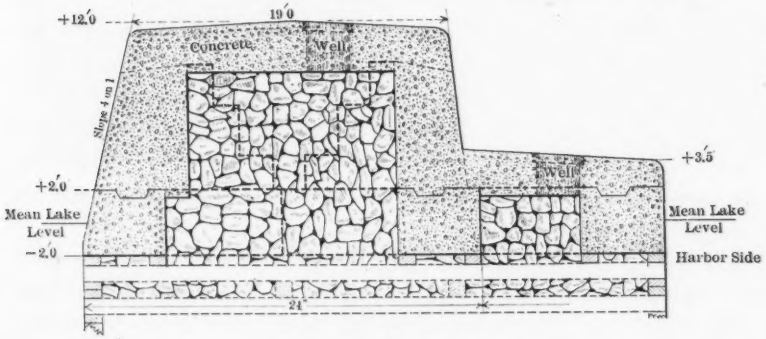
The length of the concrete superstructure built during the season was 1 967.9 ft. The volume of concrete was 25 969.28 cu. yds., or 132 cu. yds. per linear foot, the cost being $213 165.69, or $108.32 per running foot, or $8.21 per cubic yard. In 1889 this cost was $110.19 per running foot, or $9.19 per cubic yard. Experience and improved arrangement of the machinery, and especially the moving of cars by cable instead of by hand, account for the decreased cost.

All the concrete work just described was done by hired labor, under the direction of the United States Engineer Officer in Charge.

In 1898 it was recommended by Major T. W. Symons that the ice-breaker should have the wood and stone superstructure replaced with concrete. This section is 1 015 ft. long, and was built in 1873 to 1877. The section concreted in 1889 adjoins it on the north, and that built in 1891 on the south. The delay in concreting it was on account of the insecurity of its foundation. This was made secure by dumping a large quantity of large rip-rap along the lake face of the structure.

Plans and specifications were prepared during the winter of 1898–99, and the work was let to the Buffalo Dredging Co. on May 31st, 1899. The design of the new work was a radical departure from that

PLAN FOR REPLACING DECAYED TIMBER SUPERSTRUCTURE OF A PORTION OF BREAKWATER WITH A NEW SUPERSTRUCTURE OF CONCRETE AND STONE



MINIMUM CROSS SECTION
HEAVY DOTTED LINES SHOW CROSS-WALL BLOCKS AND DIVISIONS.

The Maximum Cross section extends 32 ft. on the Harbor Side and 22 ft. on the Lake Side, making a total width of 78 ft.

Scale of Feet
0 5 10 15 20

FIG. 10.

previously executed, which was a monolithic structure. Instead, Major Symons adopted what may be called a shell construction, consisting of inner, outer and cross-walls, the interior space filled with rubble and the whole covered with a heavy parapet deck of concrete. The different walls were founded on large concrete blocks, with their bases laid 2 ft. below mean lake level. The construction is shown in Fig. 10.

The contractors began the erection of a concrete plant and preparation for a floating plant on June 5th, 1899, and commenced

making concrete blocks on June 8th. They began to tear out the old superstructure on August 5th, and the first concrete block was set on the lake face at the south end on August 16th. The first concrete deposited in place was in the lake wall of Section 1, which was laid on August 30th and 31st.

American Portland cement was used, the brands being the Wayland and the Lehigh. The concrete in the blocks contained 1 part of cement, 2 parts of sand (of which 1 part was stone-crusher sand), 2 parts gravel (of which 1 part was granolithic) and 2 parts of broken stone. The exposed faces of the lake- and harbor- face blocks, for a thickness of from 3 to 6 ins., were made of granolithic concrete. The blocks were made on the north bank of Buffalo Creek, just above Louisiana Street, a dockage of about 400 ft. being used. A switch of the Erie Railroad extended into the yard, making the delivery of the material convenient. The cement for the blocks was stored in warehouses in the yard, that for the mass concrete was stored elsewhere.

The greater part of the broken stone, granolithic, and stone-crusher sand was used directly from the railroad cars, while the remainder, with the sand and gravel, was stored in piles at convenient distances from the mixer.

A 4-ft. cubical mixer was used. It revolved on a 4 in. hollow shaft through which water was supplied. About 1 cu. yd. of concrete was mixed at a time. The material was delivered to the mixer in a dump car, divided into proportional parts to admit the different materials in the proper quantities. The cement and beach sand were shoveled together before being placed in the car. The car was then drawn by steam power up an incline to a platform above the mixer, from which it was dumped into the hopper. After being turned fifteen to eighteen times, the mass was dumped into another car and drawn by steam power up an incline to the level of the top of the moulds, from which point it was propelled by hand.

The concrete was deposited in the moulds in layers of about 6 ins., and each layer was thoroughly tamped before another was put on. Five or six blocks were usually under way at the same time. On the lake- and harbor- face blocks a 4-in. piece was set upon the face side, while the regular concrete was being dumped, leveled, and partially tamped. It was then drawn out and the space filled with granolithic concrete. The whole mass was then thoroughly tamped together.

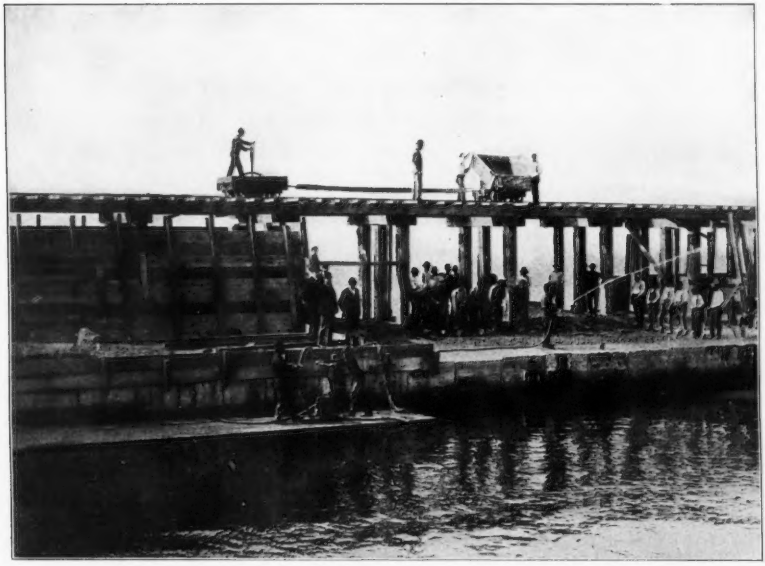


FIG. 1.—OLD BREAKWATER. BUILDING MONOLITHIC CONCRETE SUPERSTRUCTURE, 1891.



FIG. 2.—OLD BREAKWATER. BUILDING MONOLITHIC CONCRETE SUPERSTRUCTURE, 1891.

Ten or eleven blocks were made in a 10-hour day when the plant was running with a complete force. The moulds were in four rows, parallel to the dock face and as near to it as possible, occupying a length of about 150 ft., so that the blocks could be handled by a floating derrick. There was room to make from 47 to 50 blocks before any were removed. To facilitate handling, from one to three eye-bolts, depending upon the size of the block, were incorporated in the top of each block. These eye-bolts were either of new iron, 1 in. square and 3 ft. long, or were 1¼-in. drift-bolts taken from the old timber superstructure. Each had a 4-in. cast-iron washer on the lower end. The eye-bars made the handling of the blocks very satisfactory.

The moulds were of 2 in. pine, planed and matched, and the frames of 6 x 8-in. timbers, all held together by iron tie-rods. At first, 12-in. timbers were used, but were found to be too heavy. Beginning with the season of 1900 the inner faces of the lake- and harbor- face blocks were made ½ in. shorter than the outer faces, in order to make better joints. Pieces of lath were set up between the ends of the moulds and the frames, so that the frames did not have to be rebuilt.

The blocks were allowed 48 hours to set, before removing the moulds, and two weeks before being moved. When ready to be moved, they were loaded on scows by a large floating derrick and towed to the breakwater, where they were unloaded and stored.

Removing the Old Superstructure, and Repairing and Leveling Cribs.—This work required the removal of the timber and stone of the old superstructure, the repairing of the cribs when necessary, the filling of the openings between the cribs, and the careful leveling of the timber and stone, to 2 ft. below mean lake level, to receive the concrete blocks.

A specially large and powerful derrick was used in tearing out the timber and setting the concrete blocks. An old dredge was rigged for this work, the old machinery giving ample power. The anchors or spuds were found to be valuable adjuncts when setting the blocks, as they prevented the swaying or rolling of the scow and derrick.

The removal of the timber was accomplished with little cutting of timber or bolts. A pair of hooks engaged one timber at a time, and the derrick lifted it out intact or broke it off. In several places the oak sheeting gave considerable trouble and had to be sawed and taken out in sections.

During the season of 1899 a large part of the stone from the crib-work was stored on the banquette while the parapet was under construction, but in 1900 it was loaded on scows, taken to a storage yard, and there kept until needed to fill the new superstructure.

After the removal of the timber and stone to the required depth, seven cribs, uncovered during 1899, were found to be in fairly good condition. Up to June 1st, 1900, five more cribs had been uncovered, and were found to be in bad condition as to alignment. In one case the entire lake wall seemed to be gone. Piling was driven at this point, to correct the alignment. Several openings were found between the cribs, which were sufficiently large to require filling in.

The concrete blocks were set by the derrick used in tearing out the old timber. The lake-face, cross-parapet, and middle blocks were usually set in the order named, a section length being set before any concrete was moulded in place in the section. The setting of the harbor-face and cross-banquette blocks, as well as the moulding of the banquette deck, was usually left for rough-weather work.

Concrete in Place.—The concrete moulded in place contained 1 part of cement, 2 parts of sand (of which 1 part was stone-crusher sand), 2 parts gravel (of which 1 part was granolithic) and 3 parts of broken stone. The outer faces of the walls and decks, for a thickness of about 3 ins., were made of granolithic concrete.

A floating plant was used in making the concrete to be moulded in place. During the season of 1899 this plant was carried on a large dump-scow. The mixer, located on one end of the scow, was exactly like the one used for making the blocks. The derrick tending the mixer was on the same end of the scow. The materials were stored in the old pockets, which held enough for two days. The work done by this plant was in every way satisfactory; but, as the scow was not available for the season of 1900, three smaller scows were used. The mixer and two derricks, with the necessary boilers and engines, were placed on one scow, the other two being used as tenders. The decks of the tenders were enclosed, with sides 2 ft. high, and were divided into six compartments for the six different materials, and each scow was designed to carry enough material for half a day's mixing. To prevent the mixer scow from rolling, a guy-rod connected the top of the high derrick mast to the center of the tender scow.

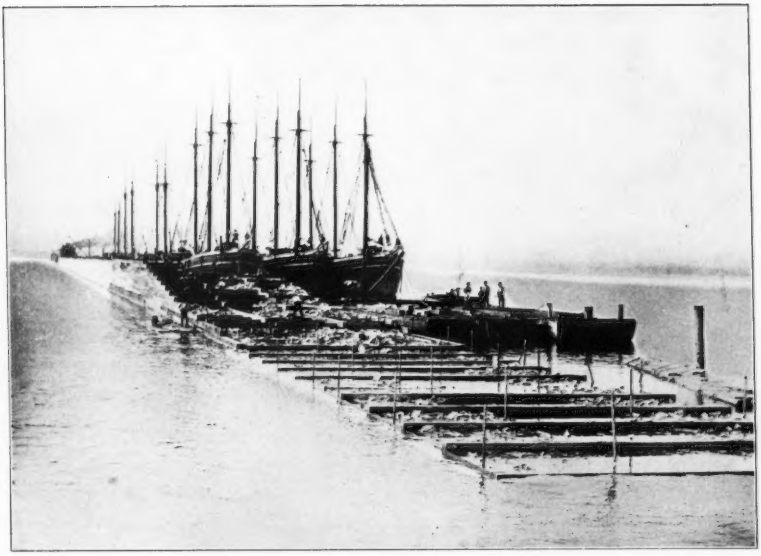


FIG. 1.—OLD BREAKWATER. BUILDING TIMBER SUPERSTRUCTURE ON CRIBS. 1891.



FIG. 2.—OLD BREAKWATER. SETTING CONCRETE BLOCKS IN INTERIOR. 1899.

The moulds for the concrete in place were of 3-in., planed and matched pine, braced with 6 x 12-in. timbers, and held together by ¾-in. tie-rods. The tie-rods in the lower row were embedded in the concrete during the construction of the wall, and were sawed off flush with the face of the concrete after the moulds were removed.

The usual procedure, in moulding the concrete in place, was to build the lake wall, harbor wall and cross-parapet walls, in the order named. Then the parapet deck was built, which completed a section of the parapet. Sometimes several sections of the parapet were completed before any work was done on the banquette. As stated before, this was left for rough-weather work. The moulding of the banquette deck completed the section, except the placing of the manhole covers. In only two instances was a failure made of completing the walls or deck of a section in one day.

The lake wall of Section 1 was the first concrete to be moulded in place, and nearly two days were required to complete it. The concrete was deposited and tamped in place in a manner similar to that followed in making the blocks. The tops of the decks were rubbed to a smooth surface with a long wooden straight-edge.

An interesting phenomenon occurred during a severe storm in the fall of 1899, when four of the manhole covers were lifted from their seats on the parapet deck and two were washed overboard, while the other two were found on the banquette deck. These manhole covers are circular plates of concrete, 3 ft. in diameter and 6 ins. thick, weighing about 530 lbs. Evidently, the cause of this phenomenon was the high air pressure under the concrete shell, caused by the wave pulsation.

The last concrete was placed on October 25th, and the last work, which consisted of fitting and placing concrete manhole covers, was done on October 28th, 1900.

The cost of this work is given in Table No. 6.

TABLE No. 6.

Removing 1 015 lin. ft. of old superstructure	at	$6.75....	$6 851.25
New hemlock timber, 11.780 ft. B. M.	"	24.00....	282.72
Concrete, 9 294.5 cu. yds.	"	6.64....	61 715.49
New stone for crib foundation, 222 tons,	"	0.66....	146.52
Timber crib filled and complete in place.....			1 475.00
Manhole covers, 42,	at	$1.25....	52.50
Mooring rings, 19,	"	30.00....	570.00
Total.....			$71 093.48

Extra Work and Materials:

Building stairs, and dressing off concrete.....		$122.50	
Excavating trenches, and fixing manholes.....		114.80	
Capping old piles, and driving new piles in foundation.....		1 221.87	
Oak piles, 1 550 ft.,	at $0.25.....	387.50	
Lumber, 392 ft. B. M.	" 35.00.....	13.72	
Iron bolts and rods, 4 139 lbs.,	" 0.06.....	248.34	
Rip-rap, 70 cu. yds.,	" 2.00.....	140.00	
			2 248.73
Grand total.....			$73 342.21

Length of work, 1 015 ft.; cost per linear foot, $72.26.

EXTENSION TO STONY POINT.

A great increase in the commerce of the harbor of Buffalo, and lack of room in the narrow channels of the inner harbor, namely, Buffalo Creek and the City Ship Canal, had for some years given rise to discussions and plans for increasing the harbor facilities. The Lehigh Valley Railroad Company had constructed at Tifft Farm, the head of the City Ship Canal, an extensive system of slips, docks and warehouses with every facility for carrying on an immense lake business through its individual line of steamers. To reach this port, their vessels were compelled to traverse a narrow channel, nearly 3 miles long. A short canal from the lake to their interior canals would obviate this, but its building was precluded by the want of a suitable breakwater to protect it. This breakwater would also enlarge the outer harbor, affording increased anchorage area for vessels,

and form a protection for the lake front southward to Stony Point, so that this locality could be utilized for commercial purposes by piers and docks built out into the harbor thus formed.

The complete wrecking of the shore-arm breakwater, on October 14th and 15th, 1893, tended to increase the public desire for a larger harbor, and, as a result of this agitation, Congress passed an act, under date of August 17th, 1894, which provided for a survey and plan for extending the outer breakwater from a point at or near the present outer breakwater southeast to a point at or near Stony Point.

In accordance with this act, test borings were made, on the line of the proposed extension to Stony Point, which showed that the material overlying the rock was nearly all soft clay, 30 to 40 ft. thick, that the rock was at a depth of from 60 to 70 ft. below the water surface, and that the clay stratum was much too soft to sustain the crib-work-type of breakwater.

Major E. H. Ruffner, the Engineer Officer in Charge, submitted a plan for the extension which provided:

First.—To complete the shore arm as originally proposed. This would be done by extending the sand-catch pier 525 ft., into 18 ft. of water, and reconstructing the shore arm, 2 750 ft. long. This project would secure the harbor area recommended by the Boards of 1868 and 1874.

Second.—To construct a detached breakwater, about 2 000 ft. long, and placed so as to protect a proposed jettied channel connecting the lake with the wharves of the Lehigh Valley Railroad Company. This new entrance channel to be built and maintained by the railroad company.

Third.—To construct a section of breakwater, 1 850 ft. long, extending northward from the Stony Point shore.

Fourth.—When necessity for further protection arose, to fill in the gap between the Stony Point breakwater and that protecting the Lehigh Valley entrance.

The proposed breakwater was to be of stone and concrete, built on a mattress of green trees, with 6 to 12-in. ends, laid in two cross-layers, wired together, and weighted by the usual foundation stone. This mat was to be of a minimum width of 60 ft. for 30 ft. depth. On this mat were to be placed alternate mattresses, of similar character, 30 ft. wide, and 2-ft. layers of sinking and holding stone, until a depth

of 17 ft. was reached. Heavy rip-rap was to be placed over the whole, filling out well the slopes, and raising the structure to 15 ft. depth. Then there was to be a 3-ft. layer of foundation stone, smaller for a bed for the concrete blocks above. The blocks, to begin with, were to be 22 ft. in length, laid crosswise, and reduced in length 2 ft. each until the desired height was reached. These blocks were to be deposited while plastic, and to set while adjusting themselves to what they rested upon.

This plan was not approved, and the whole subject of the further improvement of the harbor was referred to a Board of Engineer Officers for investigation and report.

This Board recommended the partial abolishment of the shore-arm breakwater, and the construction of a breakwater on the line from the existing structure to Stony Point, consisting of a series of rubble mounds, separated by openings about 350 ft. wide. The openings were to prevent the stagnation of the water in the sheltered area and for the convenience of commerce. The breakwater sections were proposed to be five in number, three to be 2 900 ft. long each, one 2 400 ft. long, and a shore arm 400 ft. long, a total of 11 500 ft. They were to be built *en echelon* to provide the proposed openings.

The construction was to be a mound of small rubble, founded upon a bed of gravel, back-filled into a trench previously excavated to rock, covered with large stone weighing from 4 to 10 tons. The rubble mound was to reach to a height of 12 ft. below mean lake level, and the large stone to a height of 10 ft. above this datum. The estimated cost of the breakwater was: 11 500 lin. ft., at $171 per foot = $1 966 500, or, with contingencies, $2 200 000.

The report of the Board was recommended for approval by the Chief of Engineers, and was approved by the Secretary of War on August 1st, 1895.

The River and Harbor Act, of June 3d, 1896, authorized the construction of the extension of the breakwater to Stony Point, at a cost not to exceed $2 200 000.

Under date of April 6th, 1896, the plans proposed by the Board of Engineers for this extension were reviewed critically by the Engineer Officer in Charge, Major T. W. Symons (see Figs. 11, 12 and 13), and the following modifications were suggested:

1. *Openings.*—That only one opening, 600 ft. wide, near Stony Point,

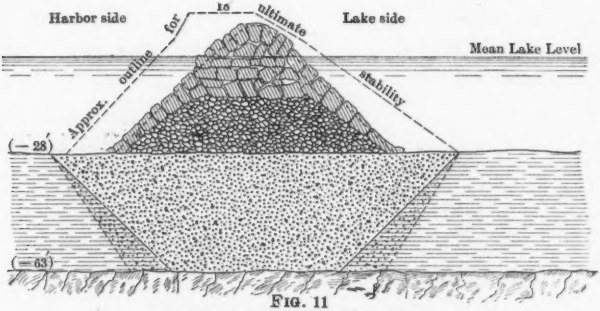


FIG. 11

BOARD OF ENGINEERS' DESIGN.

ESTIMATED TOTAL COST OF 11 500 LIN. FT. AT $191.30⅘ = $2 200 000.

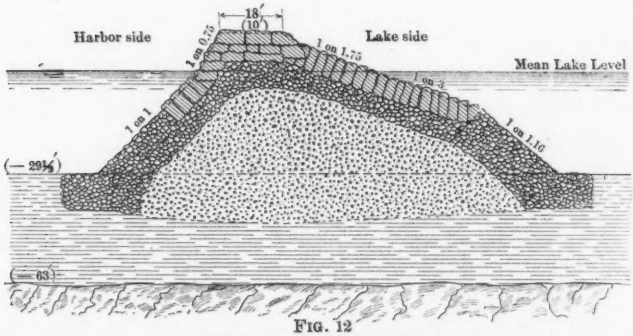


FIG. 12

TYPICAL RUBBLE MOUND DESIGN.

ESTIMATED TOTAL COST OF 12 500 LIN. FT. AT $176.13 = $2 201 650.

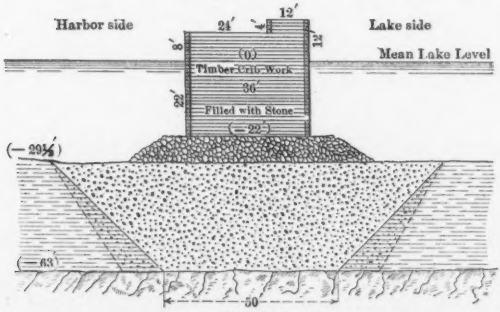


FIG. 13

TIMBER CRIB WORK DESIGN.

ESTIMATED TOTAL COST OF 12 500 LIN. FT. AT $194.00 = $2 424 191.

Scale of Feet

0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

be required; that this, with the northern main harbor entrance and a fair-weather opening between the existing and proposed work, 250 ft. in clear width, are all the openings required for the convenience of commerce. That the openings proposed by the Board do not curtail the aggregate length of the breakwater, but add expense, as the ends would have to be made much stronger than other portions. The whole structure would be less strong if built in detached portions than if these portions were united into a homogeneous whole; nor are the openings required for the circulation of the water to prevent it becoming stagnant and offensive. With a large opening, 600 ft. wide, near Stony Point, and the harbor wide open at the north end, there would be a constant circulation of water entering at the south and flowing ever toward the Niagara River. Throughout this narrow eastern end of Lake Erie, there is a constant flow toward the outlet. The natural storm effects would also aid in insuring a full and sufficient circulation of water. The openings are objectionable in permitting waves to enter the harbor and interfere with the anchorage, and also in permitting sand, borne by the general lake currents, to enter the harbor.

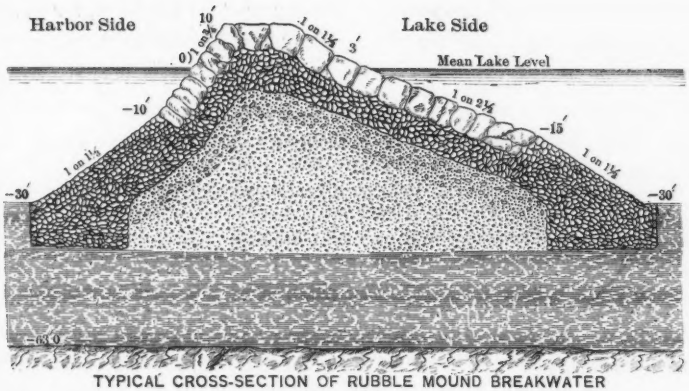
2. *The Wrecked Shore Arm.*—That instead of using a portion of this wrecked work, it be entirely removed, as, in its present location and position, it would prove a constant menace to navigation.

3. *Sheltered Area.*—That the Board's breakwater location curtails the sheltered enclosure and protected area. By moving the location of the breakwater farther out, an increase in area of 35% would be obtained.

4. *Length.*—The length of breakwater given by the Board is 11 500 ft. This does not include 1 160 ft. of the wrecked shore arm, requiring reconstruction. This would make a total length of 12 660 ft. The revised location requires a breakwater 12 500 ft. long, with but three exposed ends, as against nine in the plan of the Board.

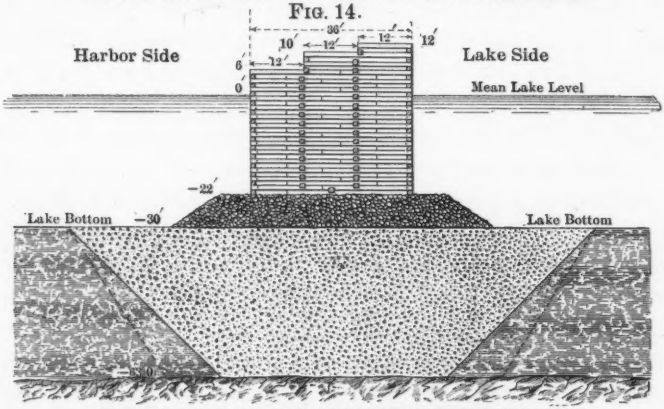
5. *Depth.*—The depth of water along the line of the proposed breakwater is about 1½ ft. greater than that along the Board's line. The difference in depth to the rock bottom is uncertain, but it is believed that there is practically no difference.

In consideration of the foregoing, Major Symons recommended that the location proposed by the Board of Engineers be abandoned, the same to be placed farther seaward and in slightly deeper water.



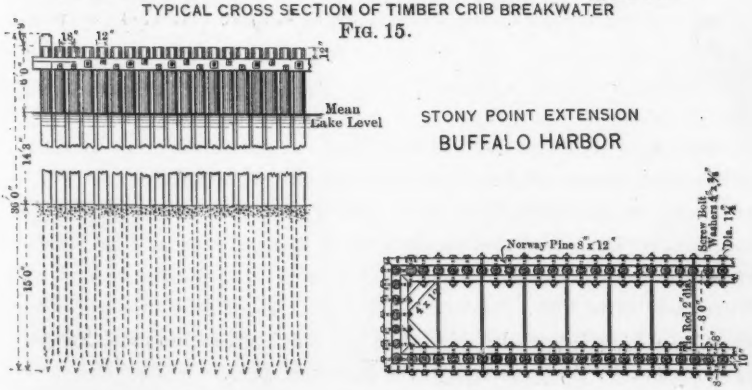
TYPICAL CROSS-SECTION OF RUBBLE MOUND BREAKWATER

FIG. 14.



TYPICAL CROSS SECTION OF TIMBER CRIB BREAKWATER

FIG. 15.



SAND-CATCH PIER EXTENSION

FIG. 16.

The breakwater now proposed would be in two sections, a 2 800-ft. section adjoining Stony Point, and a 9 700-ft. section between the Stony Point section and the existing (old) breakwater. There would be two openings, a main opening, 600 ft. wide, at a distance of 2 800 ft. from Stony Point, and a fair-weather opening, 300 ft. wide, at the junction of the old and new work.

As previously stated, the Board recommended for the whole structure a rubble mound upon a gravel foundation. In place of this, Major Symons recommended a stone structure, with a gravel hearting protected on the sides by rubble, and the whole capped with large stone, weighing 4 tons and upward, carefully placed. This large stone was to come down to a 10-ft. depth of water. The thickness of this giant paving was to be 8 ft. on top and 6 ft. on the slopes. The smaller rubble was to be 9 ft. thick on top and 6 to 12 ft. thick on the slopes. The entire structure was to be founded on the natural bottom of the lake.

This design was afterward slightly modified. It was recommended that 5 000 ft. of breakwater at the northern end be built of this type and the remaining length, to the harbor entrance, 4 700 ft., be built of timber cribwork of the dimensions of the existing breakwater, viz.: cribs 22 ft. deep and 36 ft. wide, covered with a superstructure 6 ft. high on the harbor side and 12 ft. high on the lake side.

The relative lengths of the stone and timber-crib breakwaters were subsequently changed to 7 250 and 2 739 ft., respectively. The Stony Point section, 2 800 ft. long, was to be of similar cribwork, reduced in size in shoal water. All cribwork was to be founded upon a rubble foundation, about 8 ft. high, resting upon gravel, back-filled into a trench excavated to rock.

The plans of Major Symons were duly approved by War Department endorsement, of August 11th, 1896, and, in accordance with the authority contained in the River and Harbor Act of June 3d, 1896, the work of extending the breakwater to Stony Point and the sand-catch pier to the pierhead line was advertised, and bids opened on November 30th, 1896. The contract (which is a continuous one) was awarded to the lowest bidders, Messrs. Hughes Brothers and Bangs, of Syracuse, N. Y., on January 27th and 28th, 1897.

Figs. 14, 15, 16 and 17 show the location and types of structures under which proposals were canvassed.

Table No. 7 contains a detailed statement of the quantities, according to the original estimate and the prices bid:

TABLE No. 7.

RUBBLE-MOUND BREAKWATER, 5 000 FT. LONG.

Gravel foundation and hearting.	640 000 cu. yds.,	at	$0.13	= $83 200.00	
Small and ordinary rubble.....	400 000 tons,	"	0.80	= 320 000.00	
Large capping stone.....	220 000 "	"	1.25	= 275 000.00	
					$678 200.00

or $135.64 per linear foot.

TIMBER-CRIB BREAKWATER, 4 700 FT. LONG, FROM RUBBLE-MOUND BREAKWATER TO SOUTH HARBOR ENTRANCE.

Trench excavation.....	565 000 cu. yds.,	at	$0.18	= $101 700.00	
Gravel for trench filling.....	600 000 "	"	0.13	= 78 000.00	
Rubble foundation.....	116 000 tons,	"	0.80	= 92 800.00	
Timber cribwork.....	4 700 lin. ft.,	"	92.37	= 434 139.00	
Iron mooring cleats.....	25,	"	6.00	= 150.00	
Iron mooring posts.....	25,	"	36.00	= 900.00	
					707 689.00

or $150.57 per linear foot.

TIMBER-CRIB BREAKWATER, 2 800 FT. LONG, FROM SOUTH HARBOR ENTRANCE TO STONY POINT.

Trench excavation.....	240 000 cu. yds.	at	$0.18	= $43 200.00	
Gravel for trench filling.....	250 000 "	"	0.13	= 32 500.00	
Rubble foundation.....	44 000 tons,	"	0.80	= 35 200.00	
Timber cribwork.....	2 800 lin. ft.,	"	92.37	= 258 636.00	
Iron mooring cleats.....	10,	"	6.00	= 60.00	
Iron mooring posts.....	10,	"	36.00	= 360.00	
					369 956.00

or $132.12 per linear foot.

SAND-CATCH PIER EXTENSION.

Piles.....	450,	at	$15.00	= $6 750.00	
Waling.....	1 200 lin. ft.,	"	0.25	= 300.00	
Tie-rods, screw-bolts and straps.	15 425 lbs.,	"	0.02½	= 385.63	
Transporting pile shoes.....	200,	"	0.25	= 50.00	
Stone filling.....	2 000 cu. yds.,	"	1.06	= 2 120.00	
					9 605.63
Total estimated cost.....					$1 765 450.63

Soon after being awarded the work, the contractors proceeded to establish the extensive plant required for the proper and energetic prosecution of the work. Having decided to procure large quantities of stone from Canada, they purchased a tract of land, about 80 acres, at Windmill Point, Ontario, on which a quarry was opened. To reach the navigable waters of Lake Erie, a narrow-gauge railway, about 1 mile long, was necessary, and also the construction of a loading dock, from which to transfer stone to barges.

The contractors also arranged to procure rubble from the extensive spoil banks on the Erie Canal, about 1 to 2 miles west of Lockport and

30 miles east of Buffalo. These spoil banks consist of limestone, excavated from the prism of the Erie Canal during its construction, and deposited on either side of the same. Suitable machinery to transfer this stone to canal-boats was installed there.

For the purpose of building timber cribs, a tract of land bordering on one of the slips owned by the Lehigh Valley Railroad Company, at the southern end of the City Ship Canal, was procured. This site also served as a storing yard for the immense quantities of pine and hemlock needed in the work. A building containing framing and gaining machines, circular saws, boiler, engine and air-compressor plant was also erected there. Docks and ways were also constructed.

They assembled a fleet of canal-boats, deck and dump scows, and tugs, and made arrangements for the construction of a large clam-shell dredge.

The first work on the breakwater extension was to determine the axes of the two main sections. The axis of the stone breakwater and South Harbor Section passed through a point 250 ft. seaward and at right angles to the same. This point was obtained by measuring the distance with a line and sighting across the free end of the old breakwater, which presented a plane surface, 36 ft. long. A pile was driven, and the point thus marked was designated as Station 0, being the initial point or beginning of the stone breakwater. It may be stated here that this pile was driven through Crib No. 1 of the wrecked shore-arm breakwater described previously.

The axis of this breakwater also passed through the old Lake Survey triangulation station at the extremity of Stony Point, which was marked by an iron bolt, about 2 ft. long, driven into the sand, with the top about 1 ft. below the surface. A target, consisting of a timber tripod, was placed over the bolt. An auxiliary target was also placed on the old breakwater on the axis of the new work. The two targets are nearly 16 000 ft. apart.

The axis of the Stony Point Breakwater was also fixed, by large wooden monuments, placed close to the surface of the ground, and by a range target, some 20 ft. in height, to be used during dredging operations.

The axis of the stone breakwater lies in the middle of the completed top, that of the South Harbor Breakwater lies in the middle of the parapet, or 6 ft. from the lake face, while that of the Stony Point

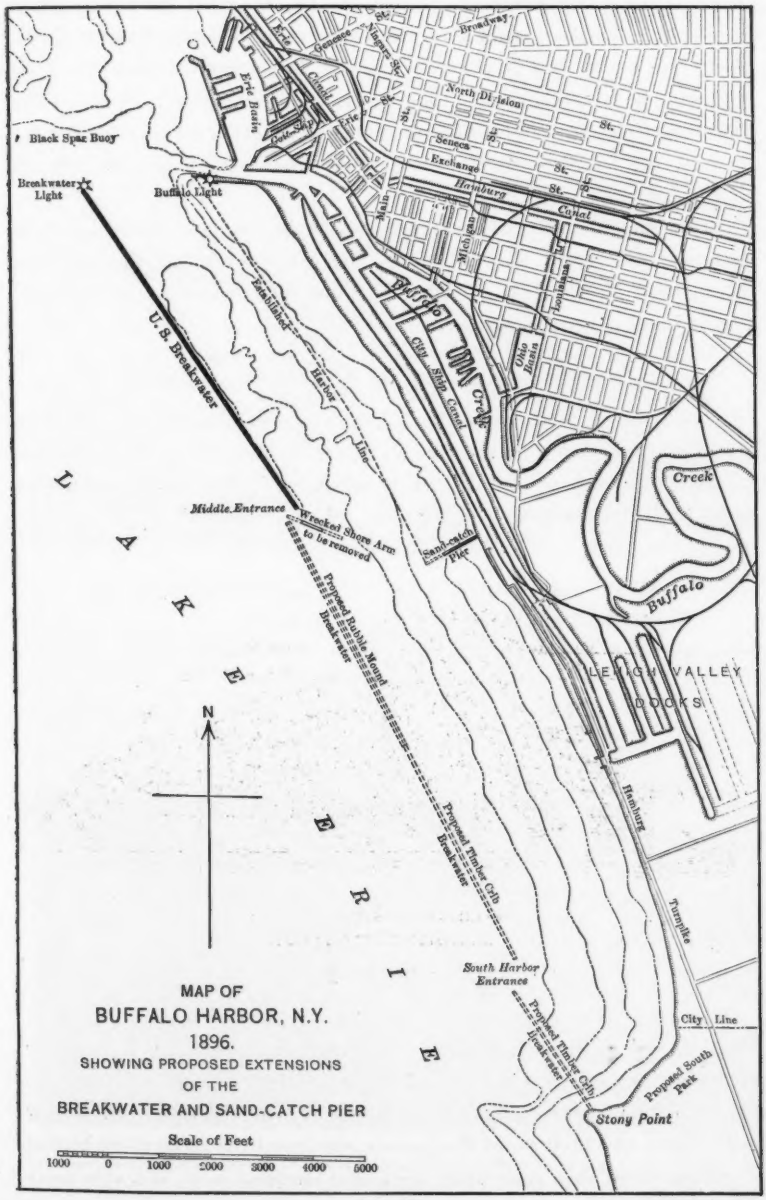

Black Spar Buoy
Breakwater Light
Buffalo Light
U. S. Breakwater
Entrance
Harbor Line
Middle Entrance
Wrecked Shore Arm to be removed
Proposed Rubble Mound Breakwater
Proposed Timber Crib Breakwater
South Harbor Entrance
Proposed Timber Crib Breakwater
Proposed South Park
Stony Point
Sand-catch Pier
Buffalo City Ship Canal
Ohio Basin
Creek
Buffalo
LEHIGH VALLEY DOCKS
Hamburg Turnpike
City Line
Erie Basin
Outer Slip
Inner Slip
Main
Michigan
Louisiana
Canal
Hamburg
Exchange
Seneca
North Division
Broadway
Niagara
Genesee
Erie
St.
N
LAKE ERIE
MAP OF
BUFFALO HARBOR, N.Y.
1896.
SHOWING PROPOSED EXTENSIONS
OF THE
BREAKWATER AND SAND-CATCH PIER
Scale of Feet
1000 0 1000 2000 3000 4000 5000

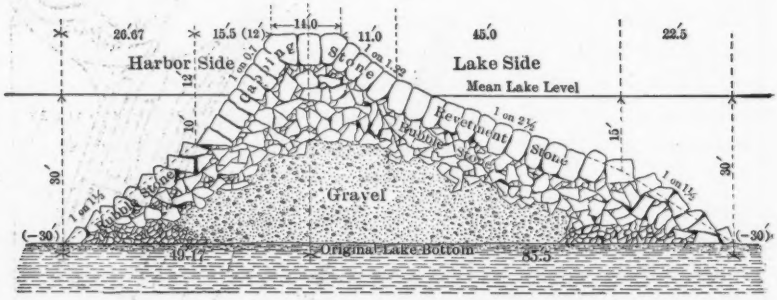
FIG. 17.

Breakwater is the lake face. These are the axes used for construction purposes. The two main axes cross each other at a point about 777 ft. from the south end of the Stony Point Breakwater, measured along the lake face of the same. The angle of intersection is 8° 53′. The bearing of the Stony Point Breakwater was determined as S. 35° 57′ E., making the direction of the stone breakwater, also that of the South Harbor Section, S. 27° 04′ E.

The construction of the extension to Stony Point was begun by the contractors, on May 19th, 1897, by placing rubble for the stone breakwater on the lake and harbor sides of the footing, of the prescribed cross-section.

The Rubble-Mound or Stone Breakwater.

The essential features of this breakwater are, the rubble ridges at the foot of the slopes on the lake and harbor sides, the gravel hearting, the rubble facing confining this hearting, and the superstructure of large revetment and capping stones.



CROSS-SECTION OF STONE BREAKWATER
EXTENSION TO STONY POINT
Scale of Feet
0 10 20 30 40 50 60 70 80

Fig. 18.

Fig. 18 is a cross-section of this breakwater as finally modified. The dimensions in 30 ft. of water, the prevailing depth, are as follows: Width at the bottom, 134.67 ft.; at the water line, 40.95 ft., and on top, 14.0 ft. The lower harbor slope is 1 on 1½, to a point 10 ft. below water level, at which point the harbor revetment* of large stone blocks

*These blocks, when under water, are termed revetment stone, and, when above water, capping stone.



FIG. 1.—STONE BREAKWATER. NORTH END. LOOKING TOWARD STONY POINT. 1899.



FIG. 2.—STONE BREAKWATER. HARBOR SIDE. STONE BLOCKS WEGIHING 17 TONS. 1902.

begins; then the slope changes to 1 on 0.7045. The lower lake-side slope is 1 on 1½ to a point 15 ft. below lake level, which is the starting point of the lake revetment; the slope of the revetment is 1 on 2½ to a point 3 ft. above water level, and above this the slope is 1 on 1.22. The height above water contemplated originally was only 10 ft., with a width of 15 ft. on top; but the height was changed to 12 ft., and the width reduced to 14 ft., hence the decimal expression of the slopes.

The theoretical cross-sectional area of the structure is 2 996.42 sq. ft., divided roughly as follows: Gravel, 950 sq. ft.; rubble, 1 450 sq. ft., and revetment and capping stone, 600 sq. ft. In actual construction, the area of the rubble was somewhat increased, as the slopes of both the lake and harbor sides were built somewhat beyond the prescribed lines.

Actual work on the structure was commenced on May 19th, 1897, and was practically completed on December 10th, 1902, on which date, and a few days later, 1 300 ft. of the harbor side of the structure, between Stations 59 and 72, sank about 12 ft. Reference to this damage will be made later. No work was done during the winter months.

Methods of Construction.—The position of the breakwater having been fixed by targets on the prolongation of the axis, piles were driven on the axial line, at 1 000-ft. intervals from the north end, and numbered 0, 10, 20, 30, etc., thus dividing the work into 1 000-ft. sections. Piles were next driven at 250-ft. intervals, at the foot of the prescribed slopes of the lake and harbor sides. The latter served as guides in placing the materials. The outside ridges were built first by dropping small limestone rubble over the sides of the canal-boats, in which the material was first brought to the work. The loaded boats were towed to Buffalo by a small steam tug. On arrival at the breakwater site, they were carefully aligned, parallel to the axis of the work, and with one side over the proposed lake- or harbor- side ridges. Then the stones were dropped one by one. These ridges were built about 20 ft. wide, and from 6 to 8 ft. high.

The usual load for a canal-boat was 200 cu. yds., or 225 tons. Usually, three boats were unloaded daily, with a force of thirty-five men. A fleet of nine canal-boats was in service, of which three were loading at the quarry, three were on the way, and three were being unloaded.

Before unloading a boat its longitudinal position was determined carefully by measurements taken from the nearest pile; its transverse position or range was taken at the same time. These notes, together with the name of the boat, the number of the ticket accompanying it, the date, time of unloading, and other pertinent information, were recorded in blankbooks prepared for the work. While unloading, the boats were held in position by lines running to anchor buoys.

After a sufficient length of these rubble ridges had been constructed, the gravel hearting was begun by depositing the gravel from dump scows.

The gravel was dredged from the bed of the Niagara River, between the foot of Ferry Street, Buffalo, and the International Bridge. Owing to the swift current of the river, especially at the water-works intake crib, where it is more than 7 miles an hour, there was great difficulty in towing the loaded scows up stream. After repeated trials with the large harbor tugs of Buffalo and Detroit River as motive power, a large and powerful tug was built especially for that service.

The gravel was usually brought to the work in dump scows, also built for the work. There were four of these scows, two of wood and two of steel, each having eight pockets. The capacity of each scow was 590 to 616 cu. yds., but, generally, they carried only from 450 to 470 cu. yds., one pocket being left empty to facilitate towing.

After a sufficient quantity of gravel had been deposited, generally a layer of 2 to 3 ft. in thickness, the rubble facing was commenced. The facing was of large and small rubble from the contractors' Canadian quarry, about 6 miles from Buffalo, and was brought to the work in dump scows.

Soon after work was commenced, it became apparent that some positive and reliable cross-ranges were necessary, to regulate the method of dumping materials. This was accomplished by stretching, between the piles at the 1 000-ft. stations, wire cables, on which wooden markers were suspended at fixed intervals. One end of the cable was attached firmly to a pile, and the other end was passed through a pulley on the opposite pile, and weighted to keep it taut. This prevented the breaking of the cables when the piles were swayed by the waves.

The position of every scowload of gravel, or rubble, was recorded in the same manner as the canal-boat stone. These data were plotted

on cross-section paper, each scow being shown in plan. With the large number of scow loads of material of different kinds, it soon became evident that this method was quite inefficient, and it was decided to cross-section the deposits regularly. A 20 x 50-ft. scow, drawing about 1 ft. of water, was utilized for this purpose. The cross-sections were taken by soundings, the scow being placed normal to the axis and held in position by anchor buoys. The soundings were taken at stations 10 ft. apart, measured along the axis of the breakwater, and at 5-ft. intervals at right angles to the same. Small flexible wire cords were used in measuring. The larger were $\frac{1}{8}$ in. and the smaller $\frac{1}{16}$ in. in diameter. The larger cords were graduated every 20 ft., and the smaller ones every 5 ft. The graduations were marked by small loops of wire passed around the cords. One end of the wire was wound around the cord several times, then a piece of $\frac{1}{2}$-in. round iron was held against the cord, and the wire passed around both several times. It was then cut off, and the bolt withdrawn. In the case of the large wire, the resulting loops served to attach wooden floats held in place by harness snaps. The 20-ft. floats were painted white and the 100-ft. floats red. The heavy wire was usually 1 000 ft. long, and the floats kept it from sinking. On the smaller wire numbered brass tags indicated the distances.

The soundings were plotted in $4\frac{1}{2}$ x $7\frac{1}{2}$-in. cross-section books, to a scale of 20 ft.=1 in. To facilitate the work, a skeleton cross-section was plotted previously on each page, a separate book being used for each 1 000-ft. section.

These cross-sections served the purpose admirably, and gave a graphic record, which showed at a glance the state of the work under water.

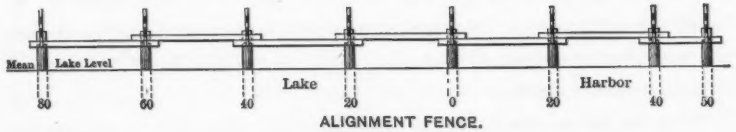
Owing to the short length of the sounding scow, which required a number of settings to cover the full width of the work, a larger and more efficient one was built. In order to secure as many cross-sections as possible without changing the scow's position, it was built with two hulls, each 10 ft. wide and 120 ft. long, separated by an open space, 10 ft. wide, thus forming a catamaran. By this arrangement four parallel cross-sections, 10 ft. apart, could be sounded from one position of the scow.

Two 8 x 10-ft. deck houses were built on the scow, one to serve as a plotting and computing room and one as a store-room for lines, etc. There were crank capstans at each end for handling anchor and moor-

ing lines. The hulls were only 3 ft. in depth, in order that the deck might be as low as possible to facilitate sounding operations, and were stiffened with suitable trussing and bracing. The vessel was most appropriately named the *Gemini*.

An inspection of the prescribed cross-section, Fig. 18, will show what an important factor this sounding was. Thousands of tons of material were being deposited daily, actually out of sight, its position being known only approximately at the moment of dumping. From an economical point of view, it was very important to know that no material was wasted outside of the prescribed slopes, and that the proper co-relation between the gravel and rubble was being maintained. This information could only be obtained by careful soundings, taken unremittingly, and following closely the depositing of material at all times. To complicate matters further, berms had to be left for the placing of the initial revetment stone on both the lake and harbor sides, at 15 and 10 ft. below water level, respectively. This required very careful dumping, and, of course, satisfactory results were only obtained by skilfully placing the dump scows on the proper ranges.

The original suspended cable ranges not proving entirely satisfactory, so-called fences, Fig. 19, were erected at each 1 000-ft. station.



ALIGNMENT FENCE.
FIG. 19.

They were composed of a row of piles, driven at 20-ft. centers, to the sides of which, near the tops, heavy planks were bolted, and to which the range sights were attached. The latter were light strips of wood, 2 to 3 ins. wide and from 3 to 6 ft. long, painted white and red, so as to be readily discernible.

The gravel was deposited to a height of 10 ft. below mean lake level, and then covered with rubble. This height was controlled, to some extent, by the draft of the loaded scows, and therefore much of the rubble over the gravel hearting had to be unloaded by floating derricks, instead of by dumping.

After the gravel had been thoroughly covered, the mound was ready to receive the revetment stone. Owing to the large size of the

rubble used for the gravel facing, its surface was necessarily uneven and not in proper condition to receive the revetment blocks. Therefore it had to be prepared properly before any of these blocks could be placed. On the lake side this was done by a method termed leveling, which consisted in dropping small stone by hand over the side of a scow having one side aligned exactly parallel to the axis of the work. Blue-print tables had been prepared showing the proper depth of the prescribed slope below mean lake level for each 2-ft. horizontal interval. The leveler in charge of the work had a copy of these tables, and, by placing the deck scow on the proper range, the desired depth was known at once. While the stone was being thrown over the edge the leveler passed back and forth constantly with a sounding pole, regulating the deposit. The scow was always worked in from the outside toward the center, moving 2 ft. at a time. By this means a fairly uniform and smooth slope was secured.

On the harbor side, the foundation for the evetment stone being horizontal, this leveling was more readily done.

The next operation was the placing of the revetment stone. On the lake side, the initial course, which is 63 ft. from the axis, was placed level, for most of the work, although at first the stones were set at an angle. The succeeding stones were then placed so as to be normal to the slope. This was attained readily by hanging them at the corners.

On the harbor side, the initial stone was triangular in shape, and was set with the apex up. The position of this apex was determined by ranges. See Fig. 20.

The revetment stones were placed without a diver, and with sounding poles in the beginning. At times the water was sufficiently clear and the light favorable for seeing the stone with the unaided eye, down to a depth of about 10 ft., under which conditions the work was much simplified.

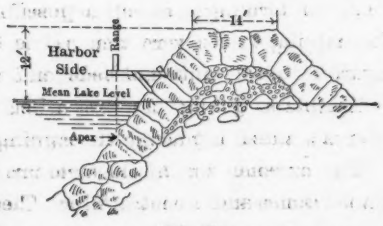


FIG. 20.

These favorable conditions of light, however, were not sufficient for the necessary examinations and inspections of the placement of the revetment stone, and therefore, water telescopes were constructed to aid in such inspection.

The tubes of the larger telescopes are of $\frac{3}{16}$, $\frac{1}{8}$ and $\frac{1}{16}$-in. steel plates, riveted together and made water-tight. The tubes are 12 ft. 4 ins. long, with diameters of 12 ins. at the object end and 4 ins. at the eye end. They are fitted with handles, and with hooks for tackle to raise and lower them, and are painted black inside. A casting, riveted to the object end of the tube, is provided with planed seats for a plane object glass, 13 ins. in diameter and $\frac{1}{2}$ in. thick, and for the rubber packing and ring necessary to make water-tight joints.

Shorter telescopes were made afterward, to suit shallower water, and there were three lengths in use, namely, 12 ft. 4 ins.; 9 ft. 10 ins., and 7 ft. 4 ins., weighing, respectively, 301, 222 and 171 lbs. These weights are somewhat less than the displacement of the tubes, thus allowing them to float about 2 ft. out of water. See Fig. 21.

The revetment blocks, which are quarried out approximately cubical in shape, with one dimension as near 6 ft. as possible, were lowered into place in juxtaposition, as nearly as practicable, so as to cover fully the rubble behind them. Of course, their approximation to the prescribed slope under water is governed entirely by the prepared foundation upon which they rest, yet it is proper to state that the variation from the prescribed lines is quite small, as frequent soundings on the finished work have demonstrated.

As the revetment stone approached the water surface, any little inequalities in line and surface were rectified, in order to obtain as straight a "shore line" as possible. At this stage the raising of the mound was followed by the deposit of more rubble, both large and small, conforming as closely as possible to the prescribed cross-section. The capping stones were then set as compactly as possible, with due regard for close joints and beds, and were well bedded.

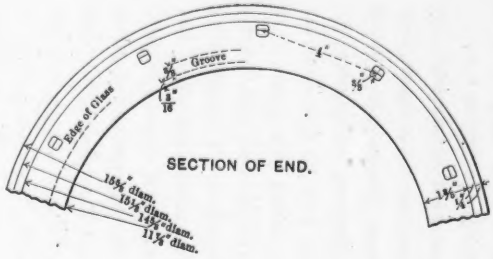
Templates giving the prescribed cross-section, placed at close intervals, aided in placing the capping stone on the required grade.

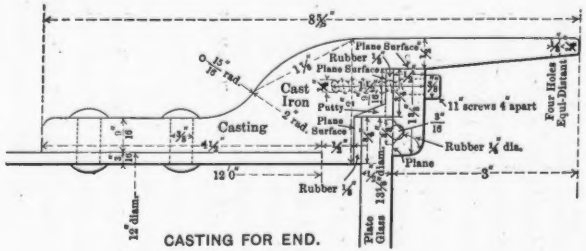
The extreme top of the structure is composed of two trapezoidal-shaped stones and a central filler. These odd-shaped stones were especially quarried by drilling and blasting, no cutting tools being used.

All the revetment and capping stones were placed by floating derricks, moored alongside the work, and held in position by hawsers leading to anchor buoys. The scows loaded with stone were placed alongside the derrick on the outside. When engaged in setting revetment stone on the lake side, small floats, averaging about 14 x 20 ft. in size, were placed between the floating derrick and the work. These floats served

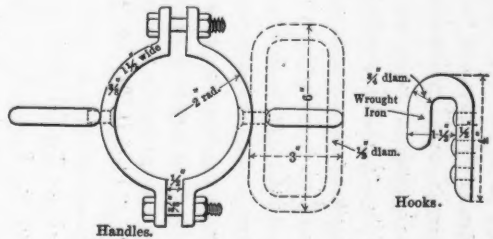
WATER TELESCOPE.

Estimated Displacement, 293.0 lbs.
" Weight, 261.5 lbs.





CASTING FOR END.



Handles.
Wrought Iron

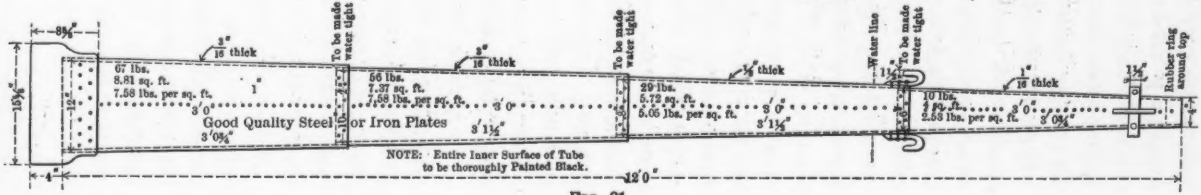


FIG. 21.

as a base for the workmen manipulating the swinging stone, and also for the Government inspector.

A working crew consisted of eight men, as follows: One foreman, having general oversight and selecting the proper stone to set; one assistant foreman, giving directions about swinging the stone, and raising and lowering the boom; two engine men, one of whom operated the main hoisting engine, the other the swinging engine; two stone pickers, picking holes for the stone hooks, and two laborers on the wall setting the stone.

The setting of the revetment and capping stone on the lake side was oftentimes retarded and suspended during westerly winds, when no work could be done on that side. This delay, later, was diminished to some extent by substituting for the original short booms of two of the derricks, two longer ones, of 75 and 90 ft., thus making it possible to place stone from the harbor side during stormy weather.

At the beginning of the season of 1899, the manner of laying the massive capping stone on the lake side was changed. During the previous season this capping stone had been laid with the longer axes of the stones perpendicular to the axis of the structure, breaking joints as well as practicable. In doing this there was some difficulty in getting close joints, which were the more objectionable as they ran from a point 5 ft. below mean lake level to the top of the rubble-mound structure. It was then decided to lay the stone parallel with the axis of the structure, the same as the revetment. This change produced a better class of work by making closer horizontal as well as perpendicular joints.

The several kinds of material, small rubble, large rubble, gravel and large revetment and capping stone, were conveyed to the work in vessels. A part of the small rubble, from quarries on the Erie Canal, was conveyed in canal-boats. The remainder of the rubble, both small and large, was conveyed by dump and deck scows, the capping only on deck scows and the gravel only in dump scows.

When bids for the work were invited, originally, prices for the rubble were asked, both by measurement by the cubic yard, and by displacement by the ton. The latter method, however, was adopted for payment, as more accurate results were secured.

As a matter of information, however, the measurement of all stone brought from Lockport, during the season of 1897, was determined by both methods, and, from a large number of canal-boat loads, it was

found that 1 cu. yd. equalled 1.125 tons. This was limestone, and averaged 166⅔ lbs. per cubic foot. It will be observed that, as loaded in the canal-boats, the voids were exactly 50 per cent. All vessels carrying material were measured accurately, and the displacement of canal-boats and deck scows was computed carefully from the data thus obtained. For the dump scows only the cubic contents of the pockets were determined.

All the vessels, except the gravel scows, were provided with glass water-gauges, located amidships, in the bow and the stern. Each gauge consists of a 3-in. wrought-iron stand-pipe screwed into the bottom of the boat. A glass tube, similar to those used for steam boilers, is connected with the stand-pipe by brass fittings. A hard-wood rule, graduated to feet, tenths and hundredths, is placed alongside the glass tube, for recording the height of the water. The rule is so placed with reference to the bottom of the boat that the readings give at the same time the exact draft of the boat. The capacity of the scows, loaded to various depths, was readily determined from displacement tables carefully prepared for each scow.

To check the calculated displacement of the scows, test weighings were made at the opening of each season. These consisted in weighing one or more loads on a track scale and making comparison with the tabulated results. A surprising agreement was found in nearly every case, the difference being only trifling.

Large quantities of rubble were brought to the work in dump scows. As the loads could not be determined by displacement, the carrying capacity of each particular scow was ascertained by reading the gauges when light, and at frequent intervals during loading, the stone all the while being weighed on a reliable track scale. By simply dividing the difference of the gauge readings into the weighed loads a ready multiplier for future loads was obtained. It may be noted here that this multiplier varied somewhat with the size of the stone.

The gravel was measured in the pockets of the dump scows. Suitable tables, giving the contents of the pockets to the deck level, and for fractional parts of feet above and below this datum, were prepared, and from these the contents of full or partial loads could be ascertained quickly.

Each scow was numbered or named, and it and its load were identified by a "loading ticket," recording the light and loaded gauge

readings, the quantity and kind of material composing its load, its running number, and the date. These tickets were issued and signed by the inspector at the place of loading. The ticket accompanied the loaded scow to the work, and a check record of the loaded and light readings, of the kind and quantity of material, and when and where placed, was marked thereon. These tickets afterward formed the basis for the reports and records of material for the monthly payments.

The construction of the stone breakwater occupied six seasons, a season's work being generally seven months, or from May to November, inclusive.

The contract length of the stone breakwater was 5 000 ft., but, while the work was in progress, Major Symons recommended that the timber cribwork section be reduced, thus adding 2 250 ft. to the stone breakwater, making its length 7 250 ft.

The gravel hearting was only delivered in large dump scows, towed up the Niagara River, during the years 1897, 1898 and 1900, practically none being placed in 1899. That deposited during 1901 and 1902 was delivered in small dump scows, towed up the Black Rock Harbor and Erie Canal, entrance to the latter being obtained through the so-called ship lock, connecting with the Niagara River immediately below the International Bridge.

In addition to the rubble from the United States and Canadian quarries, a considerable quantity was dredged from the wrecked shore arm and obtained from blasting operations in Buffalo Creek.

Table No. 8 shows the quantities of material deposited in the stone breakwater (rubble mound) for each year under construction, also the cost:

TABLE No. 8.

Season of:	Gravel, in Cubic Yards.	Rubble.		Capping stone, in tons.	Total cost.
		From United States, in tons.	From Canada, in tons.		
1897	73 184	76 417	27 501	383	$93 127.98
1898	49 569	38 802	66 681	16 079	110 928.84
1899	942	3 932	26 351	42 425	74 562.85
1900	23 781	37 292	79 685	54 989	158 675.09
1901	70 950	27 444	145 814	77 532	242 120.88
1902	26 816	19 504	118 376	93 471	228 724.12
Totals	245 242	203 391	464 408	284 879	$908 139.76

The work was practically completed on December 10th, 1902, on which date 1 000 ft. of the harbor side settled, followed on December 14th, 1902, by 300 ft. more. At this time the detailed cost was as given in Table Nos. 9 and 10.

TABLE No. 9.—Detailed Cost of Stone Breakwater.

Gravel	245 242 cu. yds., at	$0.13	$31 881.46
Rubble, from United States	202 969.3 tons, "	0.80	162 375.44
" " "	422.1 " "	0.77½	327.13
" " Canada	317 606.9 " "	0.80	254 085.52
" " "	16 315.5 " "	0.77½	12 644.51
" " "	129 921.9 " "	0.75	97 441.43
" " "	563.5 " "	0.72½	408.54
Capping stone, from Canada	142 429.1 " "	1.25	178 036.38
" " "	142 449.4 " "	1.20	170 939.28
Total cost			$908 139.69

The difference between the totals of Tables Nos. 8 and 9 is due to the fractional half-cents in the monthly payments.

TABLE No. 10.—Quantities of Materials in Stone Breakwater, and Cost.

Kind of Material.	Quantities.		Cost.	
	Total.	Per linear foot.	Total.	Per linear foot.
Gravel	245 242 cu. yds.	34	$31 881.46	$4.40
Rubble	667 799.2 tons.	92	527 282.57	72.73
Capping Stone	284 878.5 tons.	39	348 975.66	48.13
Totals			$908 139.69	$125.26

Table No. 11 shows the quantities of rubble and capping stone placed in the stone breakwater during the seasons of 1899, 1900, 1901 and 1902, also the estimated amount of labor and the resulting cost per ton of material placed.

Table No. 12 shows the quantities of revetment and capping stone placed in the stone breakwater during the working seasons of 1900, 1901 and 1902.

Administration and Regulations.—Operations on all parts of the breakwater were under the immediate supervision of an assistant engineer, who regulated the contractors' operations so as to secure the specified results, and who had general charge of the inspection and records of the work and was responsible for the official reports.

TABLE No. 11.—Quantities of Rubble and Capping Stone Placed in the Stone Breakwater During the Years 1899 to 1902; also the Estimated Cost of Labor and the Cost per Ton.

Year.	Rubble, in tons.	Capping stone, in tons.	Total tons.	Estimated amount paid for labor.	Cost per ton, in cents.
1899*.....	30 282.9	42 425.1	72 708.0	$13 615.03	19
1900†.....	116 976.7	54 988.7	171 965.4	24 428.06	14
1901‡.....	173 258.2	77 531.7	250 789.9	29 904 95	12
1902‖.....	137 879.8	93 470.9	231 350.7	30 643.76	13
Totals.....	458 397.6	268 416.4	726 814.0	$98 591.80	13½

* To handle the material in 1899 there were generally four floating derricks, one being engaged for part of the time on the adjoining timber cribwork. The average working force consisted of one superintendent, one assistant superintendent, one timekeeper, five foremen, eight enginemen, thirty-one laborers, one diver, one diver's tender and six boatmen, assisted by two or three tugs and three yawl boats. Only two scow-loads of gravel, 942 cu. yds., were deposited during the season.

† To handle the material in 1900 there were generally five floating derricks, one of them being engaged for part of the time on the adjoining timber cribwork.

‡ To handle the material in 1901 there were generally five floating derricks. There were, also, six tugs, two as tenders to the derricks, also placing stone and gravel scows, one towing gravel from the Niagara River, one towing rubble and capping stone from the Canadian quarry, one was used as a general utility boat for carrying men, supplies, etc., and one was engaged in watching at night. The quantity of gravel deposited was 70 950 cu. yds. This gravel was towed up the Black Rock Harbor and Erie Canal in small dump scows having an average capacity of 154 cu. yds.

‖ To handle the material in 1902 there were generally five floating derricks. There were also five tugs, exclusive of the tug towing gravel. The gravel hearting was completed on July 1st, 1902, 26 816 cu. yds. having been deposited during the season. The average working force was one superintendent, one timekeeper, five foremen, five assistant foremen, ten enginemen, twenty derrickmen, twenty laborers, one diver and tender, four carpenters, one leveler, one blacksmith, nine yawlmen, one cable splicer, two watchmen and two scowmen.

TABLE No. 12.—Quantities of Revetment and Capping Stone Placed in the Stone Breakwater during the Years 1900, 1901 and 1902.

Year.	Number of working days.	Revetment and Capping Stone Placed.·				Average weight of stone, in tons.	Maximum weight of stone, in tons.
		Tons.		Number.			
		Total.	Daily.	Total.	Daily.		
1900.....	164	54 988.7	335.3	8 883	54	6.20	16.5
1901.....	196	77 531.7	395.6	11 729	60	6.60	16.8
1902.....	212	93 470.9	440.9	15 452	73	6.05	18.0
Totals and averages...	572	225 991.3	1 171.8	36 064	63	6.26	18.0

On the rubble-mound construction the placement and measurement of materials were inspected and determined by a chief inspector, assisted by several inspectors as required. The placement of the

under-water materials was particularly important, and required constant supervision. This was especially so in the case of the revetment stones, great care being taken that all stones were in actual contact and set to the required grade. The harbor angle stones required more than ordinary attention. Usually, one inspector was assigned to each of the floating derricks by which all the revetment and capping stones, were set. In addition to their regular duties, these inspectors were required to submit a daily report of operations, giving in detail the kind and number of stone blocks placed, and their position in the structure. The quantity of rubble used, and where placed, were also reported when handled by the derricks. The contractors' force and plant were also noted, as well as the state of the weather, wind and sea. Delays and important happenings were reported as they occurred. Similar reports, on other blank forms, were rendered daily for rubble and gravel deposited.

These daily reports were very useful in keeping the office fully informed as to the state and progress of the work.

Weekly reports of all operations were also submitted, and these formed the basis for the monthly reports and the vouchers for payments.

The trench operations were inspected by an inspector quartered on the dredge. One inspector supervised the timber-crib breakwater construction, including the stone foundation on the trench filling, and another inspector the construction of the timber cribs at the contractors' yard. These inspectors submitted only weekly reports, but daily reports would have been very desirable.

An inspector was also stationed at the contractors' Canadian quarry, and inspected and measured the several kinds of stone. This inspector submitted daily reports giving the details of rubble and capping stone shipped, numbers or names of vessels and their loads in tons. In addition, the contractors' force and plant was reported, as well as the weather, delays and other important items. He also sent in weekly reports.

The sounding operations were under the supervision of an inspector, who directed the work and recorded and plotted the soundings as fast as made. A leadsman made the soundings, and several laborers from the contractors' force assisted in placing the scow in position.

Settlement of a Portion of the Rubble-Mound or Stone Breakwater.—The settlement of a portion of the stone breakwater during a severe storm on December 10th, 1902, which was followed by a minor settlement a few days later, has been referred to. In relation thereto, the following, taken from the official report of Major Symons, is of interest. See Fig. 22.

In making the original estimates for this work it was expected that the whole structure would settle into the underlying mud to a considerable depth, and the quantities in the estimate provided for a settlement of 10 to 15 ft.; 10 ft. on the edges and 15 ft. in the center of the structure.

As the work proceeded it was found that the expected settlement did not take place, the total settlement at any place being not more than 1 or 2 ft. The whole rubble-mound breakwater, 7 250 ft. long from its northern end to the junction with the timber-crib breakwater to the south was almost completed, with practically no settlement taking place.

About three days' more work were required to put in place the top course of capping stone at the extreme southern end, and chink a few holes in the capping. The materials necessary for this work were afloat at the site, and the contractors were making the most strenuous efforts to complete the work by working in the inclement season of the year, giving bonuses to their men, etc., when, on December 10th, 1902, during a violent storm, a length of about 1 000 ft. sank into the clay about 10 to 14 ft., thus postponing the full completion until the next season. Five days later, 300 ft. more, to the south, went down.

The drop commences at 5 900 ft. from the north end of the breakwater and extends to about 7 200 ft., almost to the timber crib. The main portion standing has been completed from one to five years, and, therefore, has had such tests as indicate its permanent stability. The portion that went down was built during the past season. The inference is that the clay bottom at the settled portion has less bearing power than it has to the north, where the structure has stood all right. This inference is strengthened by the fact that the borings taken before the work was started show that in the mud beneath the standing part there were strata of "sand," "hard sand," "gravel," "hard gravel," etc. These strata are entirely absent in the bottom beneath the settled part of the breakwater, where the borings show "soft red clay" and "very soft red clay" only.

BUFFALO HARBOR
CROSS-SECTIONS OF
STONE BREAKWATER
Harbor Side
Lake Side
Mean Lake Level
0
Gravel
Soft Clay
Rock
TYPICAL CROSS-SECTION
AS CONSTRUCTED
TYPICAL CROSS-SECTION, OF SETTLED SECTION,
1300 FT. LONG
NOTE: Outline determined by survey of Dec. 16, 1902.
Interior displacement probably as shown.
Dotted lines show proposed reconstruction.
Scale of Feet
0 10 20 30 40 50

FIG. 22.

Thus it is clear that the lake bottom with strata of sand and gravel interspersed has sufficient supporting power to sustain the structure without serious settlement, while without these strata it has not, and the breakwater built on it sank to just about the extent which it was estimated the whole would sink at the beginning of the work.

The settlement is peculiar, as only the rear portion sank, leaving the front from the water line lakeward in place and apparently undisturbed. The break occurred at the lake-side water line, the high superstructure and all the landward portion settling, on a very slight angle from the vertical, about to water level, some portions being a little above and other portions a little below water. The movement was apparently a settling and sliding landward under the pounding of the terrific seas. This indicates that the clay has sufficient sustaining power for the front, with its gentle slope and water cushion, but that the steeper rear slope with the battering of the waves was too much for it.

It is believed that the settled portion has reached such a condition as will render it safe to rebuild the superstructure on without fear of further trouble, but, to make the future more assured, it is proposed to correct the irregularities in the harbor slope and widen the base where necessary by placing more stone at the toe of the slope, as generally indicated by Fig. 22, which shows the structure as built, as settled, and as it is proposed to rebuild it.

The proposed method of repairing the damage is as follows:

a.—Place rip-rap along the harbor slope to make the general harbor slope about equal to the lake-side slope.

b.—Remove all capping stone, particularly angle stones, in the sunken portion, which can be conveniently gotten at, and use them again in the new superstructure at the proper time.

c.—Arrange the stone properly as a foundation for a new superstructure.

d.—Build a new superstructure to the same lines as the old one, making the alignment fit in with the standing portions on each side of it.

e—To add security to the entire structure, it is also proposed to place rubble along the inner slope, thus widening the harbor toe and tending to correct any inclination to settling and sliding.



FIG. 1.—STONE BREAKWATER. LOOKING NORTH, AFTER SETTLEMENT, DECEMBER 10TH–15TH, 1902.



FIG. 2.—STONE BREAKWATER. HARBOR SIDE. STRUCTURE AFTER SETTLEMENT, DECEMBER 10TH–15TH, 1902.

Non Mou

In performing this work of repair, the original contractors, Hughes Brothers and Bangs, have agreed to take up and reset all the capping stone that can be economically saved, and arrange the settled portion properly as a foundation for the new superstructure, for which work they are to receive their actual force account plus 15% and a fair rental for the derricks, boats, etc., used. All additional materials will be furnished at the original contract prices. It is expected that the entire structure will be completed early in the summer of 1903.

TABLE No. 13.—Rates of Wages Paid on Stone Breakwater.

Superintendent	$150.00 per month.
Diver	125.00 " "
Foremen (and foreman of carpenters)	75.00 " "
Hoist enginemen	65.00 " "
Timekeeper, and cable splicer	60.00 " "
Assistant foremen	55.00 " "
Swing enginemen, watchmen and scowmen	50.00 " "
Derrickmen, pickers and setters	45.00 " "
Carpenters and blacksmiths	2.25 per day.
Diver's tender	2.00 " "
Yawlmen	$1.80 and 2.00 " "
Laborers	0.15 per hour.

Stony Point Section. Timber-Crib Breakwater.

Dredging.—This breakwater extends from Stony Point in a northwesterly direction for 2 802.9 ft., into 30 ft. of water. The entire breakwater, with the exception of a few hundred feet next the shore, stands upon an artificial foundation of sand and gravel, up to the level of the original lake bottom, this material having been backfilled into a trench dredged practically to bed-rock.

The breakwater consists of five sections of timber cribwork of varying dimensions, beginning with the smallest one at the shore end, the depths of the cribs corresponding approximately with the increasing depth of water, until 22 ft. is reached, which is the maximum depth of the cribs. In deeper water they rest on a rubble foundation built up to that level.

TABLE No. 14.—Work Done by Dipper Dredges in the Seasons of 1897 and 1898.

1897.

Name of dredge.	Stations.	Days worked.	Hours worked.	Cubic yards of excavation.	Dates.	Rates.		Material.
						Day.	Hour.	
H. & W., No. 9...	0 to 2 + 40	11	(?)	315*	Aug. 4th to 23d.	28.6	(?)	Sand, hard clay, boulders with gravel.
Brian Boru.....	9 + 35 to 11 + 20	2	17	2 487	June 29th to July 1st.	1 243	146	Some sand; moderately stiff clay.
H. & W. No. 1....	4 + 50 to 3 + 00	6	43¼	1 432	Sept. 3d to 8th.	239	33.1	Clay, sand and boulders.
Brian Boru.....	5 + 00 to 3 + 80	6	54	3 209	Sept. 9th to 20th.	535	59	Hard clay and boulders.
H. & W. No. 1....	7 + 00 to 5 + 40	3⅛	21	674	Sept. 28th to Oct. 4th.	192	32	Hard clay and boulders.
Total, in 1897, 8 117 cu. yds. = 62 scowloads.								

1898.

Brian Boru.....	5 + 30 to 6 + 10	5	29¾	1 998	March 25th to April 5th.	400	67	Some clay; hard clay and boulders.
Tipperary Boy...	6 + 57 to 7 + 07	1	4¼	325	April 11th.	325	76	Hard clay and boulders; hardpan.
H. & W. No. 4....	5 + 40 to 8 + 05	7	57¾	2 611	April 30th to May 13th.	373	45	Hard clay and boulders; hardpan.
Total, in 1898, 4 934 cu. yds. = 41 scowloads.								

* This was allowed for by computing the required place measurement of the material to be removed to make the foundation.

The first dredging was done on June 29th and July 1st, 1897, in about 15 ft. of water, but, as no material for back-filling was on hand, work was stopped temporarily. Owing to the shallow cutting required at the shore end, the contractors attempted to remove the material by plowing and scraping, but this was ineffectual and had to be abandoned. Then a small dipper dredge of shallow draft (2½ ft.) began work on August 4th, 1897, and dredged out the trench to the depth required for the first section of cribs, 300 ft. long and 4 ft. deep. This dredging was necessarily slow and tedious, on account of the many large boulders in the clay. In deeper water two dipper-dredges of greater draft and capacity worked until October 4th, 1897, when dredging was suspended for the season.

Dredging was resumed on March 25th, 1898, by the dredge *Brian Boru*. During the night of April 5th and 6th, 1898, while being towed to shelter during a heavy storm, the dredge sank, and three men were drowned. Two other dipper dredges completed that part of the work.

The work accomplished by these dipper dredges during the seasons of 1897 and 1898 is shown in Table No. 14.

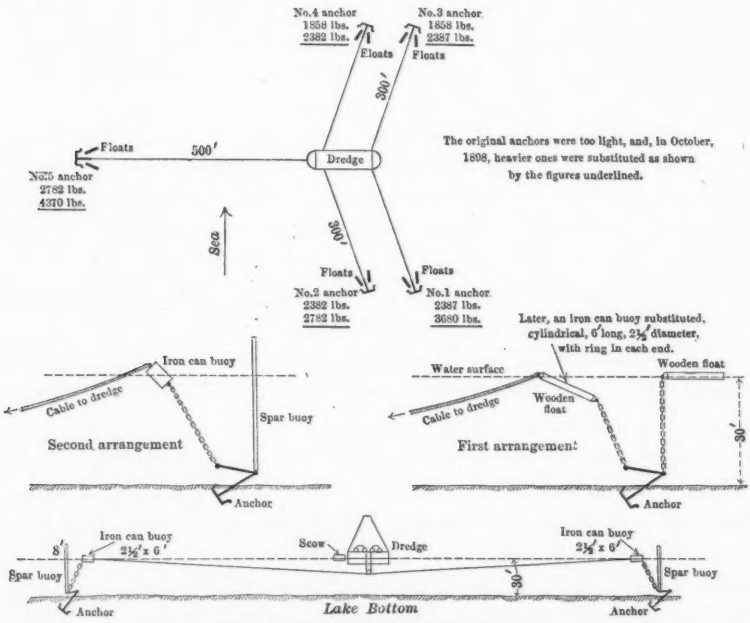
The remainder of the trench was excavated by the clam-shell dredge *Fin MacCool*, built especially for this work by the Osgood Dredge Co., of Albany, N. Y.

The hull proper is 120 ft. long, 40 ft. beam and 12 ft. 6 ins. deep. Secured at the forward end is a false bow or working platform, 10 ft. long, and aft there is a moulded false stern, 21 ft. long, added to make the dredge tow more easily and to furnish additional deck room, making the total length 151 ft. The dredge is always towed stern first. The A-frame and gallows-frame, forward, are 50 ft. high; the boom is 65 ft. long.

The usual manner of anchoring dredges in deep water is by anchor lines run out from the deck level; but as these lines would interfere seriously with the free handling of scows and tugs alongside, this dredge was supplied with two single spuds, each 3 ft. square, one at each end, which acted as attachments for the anchor cables by which the dredge was held in place. The bow spud extends 11 ft. below the bottom of the hull, the stern spud extends ordinarily 20 ft. below, but can be dropped to the bottom when the water is not more than 30 ft. deep, thus holding the dredge in place temporarily when running

cables. At the bottom of each spud there are three sheaves, two set across the spud and one fore and aft. On deck, close to the spud, are three other sheaves. The anchor cables pass from the drums over the deck sheaves, down the sides of the spuds, under the bottom sheaves, and out to the anchor buoys, stockless anchors being used.

This arrangement holds the dredge with anchors in five different directions, the lines being about 12 ft. under water, thus allowing scows and tugs to come alongside the dredge freely. See Fig. 23.



METHODS OF ANCHORING DREDGES.

FIG. 23.

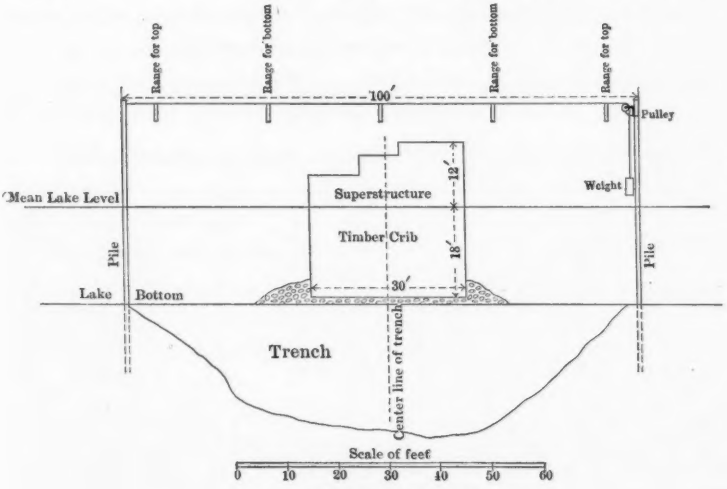
The dredge is moved by taking in or paying out the side and stern cables. The forward spud is raised by a cable attached to the hull, passing down through the longitudinal sheave and up over a sheave and thence to an auxiliary engine. The stern spud is raised by blocks and cables on the stern **A**-frame, the cables passing to the stern auxiliary engine.

The main engine, placed amidships, operates the dredge. It is an 18 x 24-in., double-cylinder engine with Stephenson reversing gear, and

is compound-geared to two 60-in. drums, with gear faces 12 ft. in diameter, and double frictions of the V-type, the male V's being of iron and the female V's lined with lignum-vitæ. The clam-shell bucket is of 10 cu. yds. capacity, and weighs 30,000 lbs.

There are also two secondary engines, one aft and the other forward, to handle the anchor and other lines. Steam is furnished by two Roberts water-tube boilers.

The trial performance of this dredge was made on March 23d, 1898, when starting work on the Stony Point section at Station 5. The hard bottom, mostly sand and gravel, which overlaid the soft clay, interfered somewhat with the progress at first. There was a little trouble,



SYSTEM OF RANGES.

FIG. 24.

also, with the hoisting cables, which had a tendency to run off the sheaves. The heating of the frictions also caused a little delay at first, especially when working in deep water, but this was soon remedied.

In the beginning, ranges to guide the work were placed on the shore and on the cribwork, which followed the dredging closely. As the trench advanced, a system of ranges, shown by Fig. 24, was used. This arrangement is the same as that used in the construction of the rubble mound. The location of the dredge, longitudinally, was determined by measuring distances from fixed piles, which were

usually driven at 400-ft. intervals, corresponding to Stations 0, 4, 8, 12, 16, etc.

This system of ranges was difficult to maintain, as the piles were not very stable in deep water, especially when subject to blows and shocks from passing tugs and scows.

Method of Work.—At first, the whole width of the trench was excavated by moving the dredge laterally, as required. In August, 1898, this method was changed. A cut, the width of the dredge, was made along one side, for 100 ft. or more, then another cut back through the center, and finally on the other side.

The dredge lay in working position all the time, except on Sundays and during violent storms, when it was towed to shelter. During ordinary storms it was allowed to tail off with the sea.

TABLE No. 15.—WORK OF THE DREDGE *Fin MacCool*, DURING THE SEASON OF 1898.

Began work March 23d, 1898; stopped work October 7th, 1898.

MONTHS.	Hours worked.	Hours delayed.	Working days.	Number of scows loaded.	Cubic yards of material dredged.	Cubic yards per hour worked.	Length of day's work, in hours.	Average load of scow, in cubic yards.	Average time to load one scow, in hours.	Average hours worked per day.	Average daily delay due to sea, in hours.
March.....	2¾	85¼	8	..	....	....	4 at 10 / 4 at 12	..	..	0.34	0.75
April.....	72	240	26	19	7 666	106.5	12	403	3.93	2.77[1]	1.81
May.....	107½	204½	26	45	14 665	136.4	12	326	2.39	4.13[2]	1.86
June.....	181½	162½	26	112	33 644	185.4	10 at 12 / 16 at 14	304	1.62	6.96	4.12
July.....	201	163	26	130	41 566	206.8	14	319	1.54	7.73	1.31
August.....	177½	200½	27	131	42 013	236.7	14	320	1.35	6.57	4.86
September.....	182½	181½	26	138	43 323	237.4	14	314	1.32	7.02	3.97
October.....	46¼	16¾	5¼	35	10 933	236.4	12	312	1.32	8.81[3]	0.57
Totals.	971	1 254	170¼	610	193 810	199.6	....	318	1.59	5.70	2.82
		1147.5[6]	161.4[5]							6.01[4]	

[1] 72 hours' delay in April, caused by wreck of dredge *Brian Boru*.
[2] 12 " " " May " " " " " " " " " " 20 " " " " " " " " tug *Pete Gorman*.
[3] 2½ " " " October, foundations of timber crib.

106½ hours = 8.87 days.

[4] [5] This value. $6.01 = \frac{971}{161.4}$, 161.4 being the total time worked less time spent on the wreck of the tug *Brian Boru*, the tug *Pete Gorman*, and in leveling foundation timber cribs; and properly should not be charged against the work.

[6] This value. 1 254 106.5 hours (as above) is the net delay chargeable to the work. Hours worked plus hours delayed = 2 118.5.

For transporting the dredged material, dump scows, ranging in capacity from 250 to 500 cu. yds., were used. The distance to the dumping grounds varied from 8 000 to 11 000 ft. The round trip occupied generally about 1½ hours. The working day, during the summer months, was from 5 A. M. until 7 P. M., or 14 hours, with half an hour for breakfast and the same time for dinner. Late in the fall the working time was decreased to about 10 hours. The crew of the dredge consisted of one runner, eight to nine men and two cooks. The work of this dredge, for the season of 1898, is shown in Table No. 15.

The greatest quantity dredged in one day was 3 565 cu. yds. on August 30th, 1898, when twelve scows were loaded in twelve hours, an average rate of 297 cu. yds. per hour. The greatest rate for one scow on that date was 430 cu. yds. per hour.

During the season of 1898 the delays of the dredge *Fin Mac Cool*, on the Stony Point Section, and their causes, were as follows:

General repairs	157½ hours.
Cables	88½ "
Heavy seas	480½ "
Anchors and placing dredge	124 "
Sheaves	37 "
Wreck of dredge *Brian Boru*	84 "
Frictions of engines	54½ "
Dump scows	55¼ "
Towing and coaling	25½ "
Wreck of tug *Pete Gorman*	20 "
Tug *Paddy Miles*	2 "
Clam	74½ "
Tugs	13½ "
Foundations of timber crib	2½ "
Holidays	14 "
Not known	20¾ "
Total	1 254 hours.

The short delay for breakfast and dinner each day is distributed among the other delays. The delay due to the wreck of the dredge *Brian Boru* and the tug *Pete Gorman* should be deducted, thus making the net delays 1 147½ hours.

The condition of the trench, while being excavated and after completion, was determined closely by soundings. The cross-sections were plotted as fast as the soundings were taken, and furnished a reliable record of the condition of the trench at all times.

When the plans were under consideration, a great deal of uncertainty existed as to the slopes at which the sides of the great trench excavated in the soft clay underlying the lake would stand. Opinions varied greatly. For purposes of estimate, the slopes were assumed at 1 on 1, and, for the standard crib, 36 ft. wide, it was intended that the trench should have a bottom width of 50 ft. It was found, however, much to the gratification of those in charge, that the slopes stood at much steeper angles than 1 on 1, and it was practicable, without increasing the quantity of excavation, to widen the bottom of the trench, this giving a greater stability to the structure. This trench excavation is an important and interesting feature of the work.

The dredging was completed on October 7th, 1898.

Cost of Dredging.—The total quantity of material excavated was as follows:

Season of 1897, by dipper dredges.....	8 117 cu. yds.
" 1898, " "	4 934 "
" 1898, by clam-shell dredge....	193 810 "
Total.....	206 861 cu. yds.

The contract price was 18 cents per cubic yard, scow measurement, making the cost $37 234.98. The place measurement of the trench is 192 258 cu. yds., showing an increase of 14 603 cu. yds. by scow measurement, or 7.6 per cent.

The following figures, showing the cost of the work to the contractor, are based upon data taken during the progress of the work, and may be assumed to approximate fairly the actual cost.

Assumed value of clam-shell dredge *Fin MacCool*.	$60 000
" " " dump scow *Protective Policy*....	12 000
" " " " " *Gold Standard*.....	10 000
" " " " " *Cuba Libre*.....	10 000
Total assumed value.....	$92 000

Annual depreciation, 10 per cent.
Annual interest, investment, 6 per cent.

Working days, Stony Point Section	170¼
" " South Harbor "	41¾
Total	212

Proportion of depreciation and interest chargeable to:

Stony Point Section	80.3 per cent.
South Harbor Section	19.7 " "
Total	100.0 " "

Depreciation and interest for one year, $14 720, chargeable to:

Stony Point Section	$11 820.16
South Harbor "	2 899.84

The following wages, as near as known, were paid during the season of 1898:

Runner	$75.00 per month.
Second runner	35 00 " "
Fireman, greaser and watchman	30.00 " "
Deck hands and cook	30.00 " "
Cook's help	12.00 " "
Extra men, without board	1.50 per day.

The cost of supplies per month for each man's board is assumed to be $12.00.

During the season of 1899, from careful records, the quantity of coal consumed per 100 cu. yds. of material excavated was found to be 0.31 ton. The cost was $1.50 per ton.

Assume 1.0 ton per 100 cu. yds. in April, 1898.
" 0.7 " " 100 " " May, "
" 0.35 " " 100 " during remainder of the season.

The expense of the siphoning-out scow *Faugh a Ballagh* was:

Engineman's wages	$40.00 per month.
Coal, 20 tons at $1.50	30.00 " "
Total	$70.00 " "

Superintendent's wages (half charged to dredge, and half to gravel filling)	$125.00 per month.
New wire cables	100.00 " "
Blacksmith shop	175.00 " "
Oil, waste, dope, etc	20.00 " "
Lines, hemp, cables, etc	40.00 " "
Miscellaneous expenses	50.00 " "
Yard expenses, ...	100.00 " "
Ranges, piles, etc., for the season	260.00 " "
Small tug, coaled, total cost	20.00 per day.
Large " " " "	25.00 " "
Large " " " "	30.00 " "

The operating expenses for the season, March to October, 1898, were then as follows:

Wages	$2 380.44	
Subsistence	907.38	
Fuel	1 212.00	
Siphoning	298.85	
Superintendence	384.62	
Wire cables	615.38	
Rope cables, lines, etc	246.15	
Blacksmith's shop	1 076.93	
Tugs, towing	6 505.00	
Yard expenses	615.38	
Ranges	260.00	
Miscellaneous	350.00	
Total operating expenses of dredge *Fin Mac Cool*		$14 852.13
Interest and depreciation		11 820.16
		$26 672.29

Quantity excavated by the dredge	193 810 cu. yds.	
Total cost per cubic yard	$\frac{\$26\,672.29}{193\,810}$	$13\frac{77}{100}$ cents.
Operating expenses, per cubic yard		$7\frac{67}{100}$ "
Interest and depreciation, per cubic yard		$6\frac{10}{100}$ "

Trench Filling.—After the trench had reached the prescribed depth, it was filled with gravel. This material was dredged by the *Brian Boru*, from the bed of the Niagara River, in the vicinity of the foot of Ferry Street, Buffalo, a short distance above the International Bridge. The dimensions of the *Brian Boru* are as follows: Steel hull, 95 ft. long, 28 ft. wide, 8-ft. sides; draft, 7 ft.; engine, 12 x 14-inch cylinders.

The first scow load of gravel was deposited in the trench on September 27th, 1897, between Stations 3 + 70 and 4 + 80. Five scow-loads were deposited during October, 1897, the last one on October 26th, 1897, a total of 2 478 cu. yds. during the season.

The two dump scows which were used for transporting this material, are entirely of steel. Each is 175 ft. long, 25 ft. beam and has 8 pockets. The capacity of each pocket to deck level is 68.5 cu. yds. or a total of 548 cu. yds. They were not loaded to their full capacity, however, on account of the difficulty in towing up the rapid current of the river. The average scow load for the season of 1897 was 413 cu. yds.

The trench filling, which was suspended at the close of the season of 1897, was resumed on April 28th, 1898, when two small scowloads of gravel, containing respectively 60 and 64 cu. yds., were deposited. The regular depositing of gravel with the large scows was not resumed until May 18th, 1898, when one scow load was placed. During the season of 1898, two large wooden dump scows were also used for transporting gravel. Each is 175 ft. long, 28 ft. beam and contains eight pockets. The capacity of each pocket to deck level is 68 cu. yds., or a total of 544 cu. yds. During the months of July and October, 1898, some smaller scows were also used in transporting gravel. The total quantity of gravel deposited in the Stony Point trench is given in Table No. 16.

The back-filling with gravel followed the excavation as closely as practicable. This was done by dumping the material from the scows until the filling reached the level of the lake bottom or the prescribed grade. The gravel, in dropping through about 30 ft. of water, spread out over the trench without forming lumps or hollows. The position of each scow at the time of dumping was noted, and was usually determined by measurement from the piles set at regular intervals, as stated previously. The position of the scows was also determined

from small spar buoys, fixed at known distances and at right angles to the axial line.

TABLE No. 16.

Month.	Number of scows.	Cubic yards.	Average scow load.
September, 1897	1	455.5	455.5
October, 1897	5	2 022.5	404.5
April, 1898	2	124	62.0
May, 1898	18	7 499	416.6
June, 1898	30	12 681	422.7
July, 1898	140	48 542	346.7
August, 1898	75	32 920	438.9
September, 1898	76	33 713	443.6
October, 1898	117	40 495	346.1
November, 1898	37	14 931	403.6
Total and average	501	193 383	386.0

Soundings over the deposited material were also taken frequently to determine its elevation and guard against putting in more than would reach above the original lake bottom.

The cost of 193 383 cu. yds. of gravel filling, at 13 cents per cubic yard, was $25 139.79.

Rubble Foundation.—The next step, after the completion of the gravel filling, was the building of the rubble foundation for the timber cribs.

In the beginning, the stone for this was brought mainly from the line of the Erie Canal, the contract not permitting the use of Canadian stone. It was brought to the work in canal-boats, and was deposited by being dropped over the sides, piece by piece.

As on the stone breakwater, the canal-boats were aligned carefully on the site of the work, and moved laterally across the same as the work progressed. The fixed grade below mean lake level being known, the elevation of the foundation was regulated by sounding continuously with a graduated pole, having an iron cross-piece at the bottom, to prevent it entering the interstices of the stone.

Later, in deeper water, the lower part of the foundation was built by dumping stone from dump scows, then topping out with stone deposited as mentioned above. In this later work, Canadian stone was used, a supplemental contract having been entered into, to allow its use.

The cost of the rubble foundation was as follows:

Foundation stone from United States	12 605.2 tons at 80 cents	$10 084.16
Foundation stone from Canada	6 363.1 tons at 75 cents	4 772.33
Rubble wall stone	202.5 tons at 80 cents	162.00
Totals	19 170.8	$15 018.49

Timber Cribwork.—As previously stated, the Stony Point breakwater is a timber-crib structure filled with stone, resting upon a rubble foundation, placed upon gravel filling.

The substructure consists of a number of cribs of different widths and depths, but of uniform length, except in one case. Where the depth of the water was 22 ft. or more, the so-called standard cribs, 60 ft. long, 36 ft. wide and 22 ft. deep, were used. In the shallow water, as the shore was approached, the width and depth of the cribs were reduced to correspond.

The superstructure varies in the different crib sections; the height of the banquette on the harbor side is uniformly 6 ft. above mean lake level; that of the parapet, for a distance of 420 ft. at the shore end, is 8 ft., the remainder being 12 ft. The dimensions of the different sections are shown in Table No. 17.

TABLE No. 17.

Cribs.				Superstructure.					
				Banquette.		Middle Deck.		Parapet.	
No. of section.	Width, in feet.	Depth, in feet.	Length, in feet.	Width, in feet.	Height, in feet.	Width, in feet.	Height, in feet.	Width, in feet.	Height, in feet.
1	16	4	300.0	8	6	None.		8	8
2	16	8	120.5	8	6	None.		8	8
3	24	12	360.8	12	6	None.		12	12
4	30	18	541.1	10	6	8	10	12	12
5	36	22	1504.5	12	6	12	10	12	12
Total..	.....	.....	2826.9	.....	.....	.....	.....	.....	.....

All heights are above water level.

Designs.—The cribwork is the same in general design as that heretofore used in the "old" breakwater, but several changes were made in the details, the most important being as follows:

Corner and Side Posts in Cribs.—Corner posts and side posts are screw-bolted to the crib walls and cross-ties. These posts do not extend up into the superstructure, but only to the top of the cribs, and are intended, principally, to strengthen the cribs below water level anticipatory to placing a concrete superstructure upon them in the future. The cribs are 60 ft. long, and posts are set in each corner and two at equal spaces along, the lake and harbor walls, making eight posts in each crib.

Grillage Planking in Cribs.—The grillage planking is confined to the middle third of the crib, leaving ample space for the stone filling to run out under the crib walls and support them in case of undermining.

Drift-Bolts in Cribs.—Button-head drift-bolts are used throughout, in place of headless bolts, for the timbers above the grillage bottoms.

Cross-ties in Cribs.—Longitudinal and alternate cross-ties are made up of three pieces of timber overlapping each other, and securely bolted, thus avoiding an unnecessary number of 36-ft. sticks of timber and obtaining a diversified bill of timber.

Benches in Superstructure.—The superstructure in the former construction (after 1887) was 8 ft. high and 36 ft. wide, surmounted on the lake side by a parapet 4 ft. high and 12 ft. wide. In order to distribute the weight of stone filling more evenly, the superstructure is designed in three "benches," the first 6 ft. high and 12 ft. wide, the second 4 ft. high and 12 ft. wide, and the third, or parapet, 2 ft. high and 12 ft. wide. The banquette is thus lowered 2 ft., which reduces the likelihood of the guards of vessels moored to the breakwater "hanging" on the breakwater wall. The height of the structure above water on the lake side remains, as heretofore, 12 ft.

Deck Planking in Superstructure.—The deck plank is laid lengthwise with the breakwater, instead of crosswise, and there are walings along all edges, in order that mooring lines may not catch in the cracks and wrench off the planks.

Mooring Posts in Superstructure.—Iron mooring posts and cleats are used, instead of mooring rings, which are inconvenient for heavy lines. The posts and cleats are set alternately along the banquette, about

100 ft. apart. The posts are intended for use when the cleats may have been covered with ice and thus rendered unserviceable.

Timber.—All the timbers in the cribs are 12 ins. square, with the exception of the grillage plank and cross-tie supports, which are 6 x 12 ins. The length of the timbers varies from 7 to 36 ft. The cribs are of hemlock, except the three top courses and the upright posts, which are of white pine. Square butt joints are used in the side and end walls. At the corners the timbers are left with their full dimensions, the side and end timbers overlapping each other alternately.

The cribs consist of two essential parts: The grillage bottom, made up of three courses of timber firmly fastened by screw-bolts; and the remaining part, made up of nineteen courses, securely fastened by drift-bolts.

The side walls are connected by cross-ties, spaced at 10-ft. centers (except in the first bottom course, where they are at 5-ft. centers). Half the cross-ties are in one piece, the full width of the cribs, 36 ft., while those of the other half are in three pieces overlapping each other. The cross-ties are gained into the side walls. The gains are fan-shaped, 12 ins. wide at the outer, and 9½ ins. wide at the inner, end. The depth of the gains is 12 ins., 6 ins. being cut out of the so-called receiving, and 6 ins. out of the covering, course. The tie-heads correspond to these dimensions, and are the full depth of the timber.

There are two rows of longitudinal ties in each crib, spaced at 13-ft. centers. They are usually 22 ft. long, overlapping each other. The cross and longitudinal ties are spaced so as to permit the crossing of the timbers without cutting. At all intersections the two are fastened by drift-bolts 24 ins. long.

The grillage floor is made up of one row of 12 x 12-in. timbers extending the whole length (in the center) of the crib, and four rows of 6 x 12-in. plank. As first constructed, these planks were confined to the middle third of the cribs, that is, between the two rows of longitudinal ties. Although spaced with 1-ft. intervals, experience demonstrated that the stone filling did not pass through these narrow openings, but left large spaces entirely devoid of stone. Subsequently, two rows of planking, one on each side of the center longitudinal, were removed and placed one on each side of the outer longitudinal. This gave two openings, the entire length of the crib, each 3 ft. wide.

The bottom of the lower series of cross-ties is 6 ins. higher than that of the side and end walls, leaving a space of that depth under the same. This allowed more or less settlement, to avoid which, 6 x 12-in. pieces of timber were attached to the bottom of some of the ties, giving them equal bearing with the side walls.

The timbers of the side and end walls above the grillage are fastened with drift-bolts, 32 ins. long, driven in each course, passing through two whole courses, and entering 8 ins. into the third. The bolts are also arranged so that there are two in each course in each bay or panel formed by the ties. The bolts are driven at a slight angle, to prevent one striking another.

The posts in the corners and at the sides are 22 ft. long. The corner posts are screw-bolted to the crib walls, and the side posts to the crib walls and cross-ties.

All screw-bolts are 1¼ ins. in diameter and have two round steel washers, 5 ins. in diameter and ½ in. thick. The heads of the screw-bolts passing through the corner posts and end walls are countersunk, and, consequently, are 1½ ins. shorter than those passing through the corner and side posts and side walls. The countersinking allows the cribs to come into actual contact when sunk in position. In some few cases the upper screw-bolts passing through the side walls were also countersunk, to prevent being bent by straight-sided vessels moored alongside the breakwater. The heads of the screw-bolts fastening the grillage walls were also countersunk.

After each covering course was placed, a 24-in. drift-bolt was driven through it and through the tie-head into the receiving course.

As mentioned previously, a diversified bill of timber was secured by putting in the side walls timbers in even lengths of from 12 to 26 ft., the various lengths being placed in such sequence as to break joints well.

The arrangement of the cross- and longitudinal- ties was such as to form series of pockets or recesses, thus avoiding the continuity of straight walls, the projecting timbers forming rests for the interior stone filling.

Tifft Farm Framing Yard.—The cribs were built at a construction yard established by the contractors at the extreme south end of the Buffalo City Ship Canal, on property owned by the Lehigh Valley Railroad Company, and known as the Tifft Farm docks. Timber and supplies were delivered there by vessel and by rail.

The construction yard covered an area of about 600 x 200 ft., the length fronting on a slip of the City Ship Canal. Facing this slip was a dock, 300 ft. long and 30 ft. wide, supported by two lines of piles, one driven along the outer edge and the other down the center. These piles were capped with 12 x 12-in. timbers, with their inner ends resting upon the bank. The piles were spaced at about 9-ft. centers. Two timber fenders were bolted to the outer row. The floor of the dock was composed of 3-in. plank securely spiked. There were three derricks on this dock, two large ones for handling timber for crib construction, and a smaller one for loading scows with timber for the superstructure.

The launching ways were about 150 ft. south of the dock, and consisted of a skeleton timber structure, supported at the outer end by piles. Back of the launching ways were two timber platforms, one 16 x 56 ft., the other 12 x 34 ft., and between them there was a derrick for transferring timber from the platform to the work on the ways. Timber arriving by rail was unloaded by a derrick.

An office, a store-house, dwellings and other buildings completed the plant, to which was added, later, a building containing saw-mill, gaining and tie-head machinery.

The hemlock timber was cut in Elk and Jefferson Counties, Pa., sawed and shipped from Carrier Station, on the Buffalo, Rochester and Pittsburg Railroad, to Buffalo, and thence over the tracks of the Lehigh Valley Railroad to the framing yard. The pine timber came from Michigan, being shipped from Marquette to Buffalo by vessel.

The grillage bottom, composed of three courses of timbers and ballast floor, was constructed on the ways. The corner and side posts were also attached in place. The structure was then launched and the required courses of side and wall timbers added, as well as the interior ties.

The framing of crib No. 1, one of the smaller shore-end cribs, 4 ft. deep, 16 ft. wide and 60 ft. long, was begun on July 23d, 1897. It was built entirely of hemlock, and contained no posts.

At the end of the working season of 1897, seventeen cribs had been launched, of which five were 4 x 16 x 60 ft., one was 8 x 16 x 120 ft., six were 12 x 24 x 60 ft., and five were 18 x 30 x 60 ft. Twelve of these cribs were wholly completed, while five of the 18 x 30 x 60-ft. cribs were only partly completed, generally lacking the three top courses

of pine. During the working season about one crib per week was launched.

During the season of 1897, 640 120 ft., B. M., of timber were framed at the yard. The average working force was one foreman, two carpenters, eight laborers and one team with driver.

Work at the yard was resumed on May 16th, 1898. Crib No. 21, the last of the cribs of reduced section, was finished on June 24th, 1898. Crib No. 22, the first of the cribs of standard section, 22 x 36 x 60 ft., was launched on June 6th, 1898. It contains 82 584 ft., B. M., of hemlock, and 15 096 ft., B. M., of pine—a total of 97 680 ft., B. M. A summary of the bolts in this crib is given in Table No. 18.

TABLE No. 18.—Bolts in Crib of Standard Section.

Kind of bolts.	Number.	Length, in inches.	Diameter, in inches.	Weight of each, in pounds.	Total weight, in pounds.
Screw-bolts, with washers.	57	37	1¼	18.70	1 065.90
" " " " .	154	26½	1¼	15.12	2 323.48
" " " " .	44	25	1¼	14.58	641.52
Drift-bolts.....	684	32	1⅛	8.96	6 128.64
" "	600	24	1⅛	6.70	4 020.00
Spikes.....	102	12	½	0.85	86.70
Total weight.....					14 271.24

The weight of each screw-bolt includes one nut and two washers. The washers were 5 ins. diameter and ½ in. thick.

The theoretical quantity of rubble required to fill one crib is 1 442.18 cu. yds.

Owing to insufficient depth of water in the Buffalo City Ship Canal to float the standard cribs, they were only framed nineteen courses high at the yard. The remaining three courses of pine were placed on the cribs after towing them to Stony Point.

Considerable work was done at the framing yard during the season of 1898. Thirty-three cribs were launched, of which four were of the reduced section, 18 x 30 x 60 ft., the others being of standard size. The quantity of timber framed and placed in the cribs at the yard during the season was 3 022 928 ft., B. M. Generally, two cribs at a time were under construction. The force was two foremen, thirteen to eighteen carpenters, from thirty to thirty-eight laborers, and three teams with drivers. During the busy part of the season two cribs per week were launched.

During 1898 two machines for cutting gains and tie-heads were installed, but it was late in September before they were in running order. Late in the fall the contractors also concluded to build the cribs in lengths of 180 ft., but with the usual crib bottoms. Three of these were bolted together, and the courses above them were made continuous. At the close of the season, one crib of this length was under construction, having been built nine courses high. These cribs were intended for the South Harbor Section.

Work at the Breakwater Site.—The first crib was sunk on August 26th, 1897. Its dimensions were 4 x 16 x 60 ft., being one of five of that size. At the end of the season of 1897, six cribs had been placed, 180 ft. of superstructure had been completed and 240 ft. were partly finished.

A storm on November 6th, 1897, the wind blowing 50 miles an hour, moved the outer end of the unfinished work 1 ft. toward the harbor side. It is likely that the narrow width of the rubble foundation on that side aggravated this movement.

On April 11th, 1898, operations at the breakwater site were begun, and consisted in the rectification of the outer end of the work which had been displaced. After this had been rectified the superstructure was commenced, and on May 28th, 1898, 420.5 ft. of breakwater had been completed. The first crib of the season was sunk on May 25th, 1898, and others followed rapidly. The first standard crib, as well as the last crib of reduced section, the two being coupled together, were placed on July 26th, 1898. The last crib was sunk on December 3d, 1898, making a total of thirty-six cribs during the season.

All the cribs rest upon a foundation of rubble, which, for the standard cribs, is about 8 ft. deep. The lower part of this foundation was built by dumping stone from dump scows, after which it was brought up to the proper elevation by casting stone overboard from deck scows and canal-boats. The latter were usually moored along the inner or outer edge of the foundation, and then moved across gradually as the work progressed.

To attain the proper elevation of the stone, a workman with a sounding pole walked continually along the edge of the vessel, constantly testing the depth, due allowance being made for the variation from mean lake level, thus securing a comparatively level foundation.

In sinking a crib, the inner end was held in close contact with the

one previously sunk, the outer end being held in position by cables leading to large stone-anchor buoys and drawn taut by capstans placed temporarily on the cribs. The sinking was done by loading stone on a temporary deck on the crib, until it had sunk to 6 or 8 ins. above mean water level, as indicated by the water gauge. Stone was then thrown into the crib along the sides, in order to prevent further sinking.

It should be mentioned that the bottom of the crib is kept about 1 ft. above the top of the foundation, the latter being built to admit this. The tendency of the stones cast along the sides is to find their way under the side walls, forming a uniform support. Of course, this is mainly dependent on the size of the stone, small stone being preferable. The filling of the cribs proceeded simultaneously from both sides, vessels with stone being moored close along each side of the crib. The stones were cast in by hand. The alignment of the cribs was regulated by a transit on the completed work. In the case of the Stony Point breakwater, the lake face was used for the axis.

The construction of the superstructure was similar to that of the cribs, as far as sizes of timbers and arrangement of cross- and longitudinal- ties are concerned. The standard plan consists of three decks, designated, respectively, the banquette, middle and parapet decks. The first is 6 ft. high, the second 4 ft. high, and the third 2 ft. high, and each is 12 ft. wide, the total height above water on the lake side being 12 ft.

The cross-ties are spaced at 10-ft. centers, except those immediately supporting the different decks, where they are spaced at 5-ft. centers. The cross-ties of the lower part of the superstructure, or below the banquette level, were made up, alternately, of whole timbers and of three overlapping pieces of timber. The cross-ties of the middle deck were uniformly 24 ft., and those of the parapet deck 12 ft., long. The longitudinal ties were from 22 to 23 ft. long.

The deck planks were laid lengthwise with the structure, with 6 x 12-in. walings along all edges. The specifications required these planks to be 12 ins. wide, but, owing to the difficulty of getting such a large number of this width, the contractors were allowed to use plank 8 ins. wide on the parapet deck, 10 ins. wide on the middle deck, and 12 ins. wide on the banquette deck.

Iron mooring posts and cleats are set alternately along the banquette deck.

In December, 1898, the close of the season, there had been completed 2 345.4 ft. of breakwater on the Stony Point Section, and, in extension thereof, 240 ft. of cribs had been sunk in place on the rubble foundation, and were left exposed to the winter's storms with practically no protection.

The third season's operations were begun on May 8th, 1899. The finished portion of the section, exposed to the winter's storms, was found to be in perfect condition. The 240 ft. of cribs in extension thereof were also found in good condition, having been only damaged slightly at the outer lake corner, where the crib wall had been torn out, for 4 ft. in depth, and the stone filling washed out. This damage was thoroughly repaired and the cribs refilled with stone. On the completion of these repairs the work of setting the four cribs remaining to complete the required length, and the building of the superstructure was commenced.

At the close of the fiscal year, June 30th, 1899, this superstructure was finished, completing the entire Stony Point Section. The length of the section is 2 802.9 ft., measured along the axis. An L at the outer end, as provided by the supplemental contract of September 26th, 1898, projects shoreward 24 ft. beyond the general harbor line, making the total length of the structure 2 826.9 ft.

TABLE No. 19.—Cost of Timber Cribwork.

Timber crib,	300.0	linear feet	at	$14.41		$4 323.00
" "	120.5	"	"	"	19.65	2 367.83
" "	360.8	"	"	"	41.27	14 890.22
" "	541.1	"	"	"	67.48	36 513.43
" "	1 504.5	"	"	"	92.37	138 970.67
	2 826.9					
Mooring cleats, 14 at $6.00						84.00
Mooring posts, 10 at $36.00						360.00
Extra work on L at north end						725.96
Repairs, contract of Charles A. Dennis						3 819.46
						$202 054.57
* Deduct 40 454.2 tons filling stone (Canada) at 5 cents						2 022.71
						$200 031.86

* This deduction was made on account of allowing the contractors the privilege of using Canada stone, in lieu of United States stone as per original contract.

TABLE No. 20.—Quantities of Material Used in the Stony Point Timber-Crib Breakwater:

No. of section.	Number of cribs.	Timber.		Screw-bolts, in pounds.	Drift-bolts, in pounds.	Spikes, in pounds.	Number of cleats.	Number of posts.	Foundation stone, in tons.	Filling stone, in cubic yards.
		Hemlock, in feet, B. M.	Pine, in feet, B. M.							
1	1–5	56 560	103 797	2 848	15 579	1 565	.....	.....	66	1 391
2	6	24 800	60 896	2 696	8 518	607	.....	.....	392	787
3	7–12	185 184	271 613	14 487	45 984	2 591	5	.....	3 633	5 162
4	13–21	559 548	514 626	35 197	117 116	5 099	3	4	5 027	13 000
5	22–46	2 064 600	1 583 149	101 620	380 446	16 761	6	6	9 850	50 911
Totals, 46		2 890 692	2 534 081	156 848	567 643	26 623	14	10	18 968	71 250

203 tons of rubble were also used for a stone wall at the shore end.

This breakwater withstood successfully the severe gales of December 5th and 12th, 1899, and also that of September 12th, 1900. The very severe gale of November 21st, 1900, however, caused some damage to the parapet deck, especially at the outer end. This damage consisted mainly of the breaking of the upper ties, which formed the direct support of the 3-in. longitudinal deck, and, consequently, the partial wrecking of this deck. The cause of the breaking of these ties was probably the excessive spans between the supports, namely, 10 ft.

In making the necessary repairs, some material changes were made in the parapet. These consisted in the removal of the 3-in. longitudinal deck and the substitution of a 6-in. deck laid transversely and supported by two rows of longitudinal stringers. Considerable blocking was also inserted between the ties, adding greatly to their bearing power.

South Harbor Section. Timber-Crib Breakwater.

Dredging.—The original plans for the extension to Stony Point provided for the construction of a 9 700-ft. section of breakwater, beginning at a point even with the south end of the old breakwater, but 250 ft. lakeward therefrom, and extending thence south in a straight line; the northern 5 000 ft. to be of the rubble-mound type and the remaining 4 700 ft. to be of the timber-crib type upon an artificial foundation extending down to solid rock.

The northern end of this main breakwater section is now known as the Stone Breakwater and the southern end as the South Harbor Sec-

tion. Before construction was commenced on the latter, a slight change was made in the South Harbor opening or entrance, and this, coupled with some minor changes, increased its length to 4 989 ft., the same as the stone breakwater, making the combined length 9 989 ft.

While work was in progress on the South Harbor Section, the Chief of Engineers, on August 21st, 1899, approved the recommendation of Major Symons to reduce its length, and to increase the length of the stone breakwater accordingly. This added 2 250 ft. to the rubble-mound section, and reduced the length of the South Harbor Section correspondingly, making it 2 739 ft. long.

As stated elsewhere, the excavation of the Stony Point trench was completed on October 7th, 1898, on which date the clam-shell dredge *Fin MacCool* commenced work on the South Harbor Section.

The ranges for keeping the dredge on the alignment had been erected a short time before, and consisted of pile clusters, with cables stretched between and range boards hung from them. The cables were placed only 7 ft. above the water surface, as it was not necessary to run tugs between them. The ranges are shown by Fig. 24. There was more or less trouble in the maintenance of these ranges, caused by storms and heavy seas washing out the pile clusters, and they were replaced by single piles, and these also failed. After they became so completely broken down that they could not be maintained, only a single cut, 40 ft. wide, was made along the center line.

A great deal of time was lost, owing to the heavy seas, and work was finally abandoned for the season on November 24th, 1898, the weather becoming very cold and stormy.

Up to this time, 41 118 cu. yds. of material had been dredged, the depth of the excavation averaging 50 to 55 ft. below mean lake level. No part of the trench, however, was completed at this time.

The principal delay was caused by the frequent storms. On October 22d, 1898, a gale arose so suddenly that in twenty minutes there was a raging sea, the waves running even with the deck. The work of letting go the anchors was commenced immediately, but took much time, and the stern cable had to be cut. The attending tug not being able to handle the dredge, it drifted rapidly toward shore, and its beaching was only prevented by dropping the bow spud to the bottom when in the breakers about 1 000 ft. from shore. At this moment

assistance came from the largest harbor tug in Buffalo, and the dredge was towed to shelter. Fortunately, little damage had been done.

Work for the season of 1899 was resumed on the trench on May 5th. The ranges suspended from wire cables were abandoned, and piles were driven instead, back ranges being erected on the Stony Point breakwater.

The method of dredging was as follows: A lake-side cut, about 100 ft. long and 35 to 40 ft. wide, was first made, then the dredge was shifted to the middle and worked forward the same distance, then shifted to the harbor side and worked backward, as on the lake side, thus making three parallel cuts. Several hundred feet of trench having thus been excavated, the dredge was moved to the point of beginning and the bottom of the cut thoroughly cleaned up.

After the first crib on the South Harbor Section had been placed in position it was used for the emplacement of the back ranges. The longitudinal location of the dredge was determined by measurement from fixed piles, as on the Stony Point Section, and also from fixed spar buoys, set to one side at right angles.

Three steel scows were used to transport the excavated material, and one wooden scow was used for a few days.

The general dimensions of the tug *Shaughraun*, used in towing the dredged material to the dumping grounds, off the mouth of Smoke's Creek, are: Length, 54 ft.; beam, 14 ft.; draft, 6 ft.; gross tons, 29; net tons, 14; iron hull; wheel, 54 ins.; engines, 12 x 15-in. cylinders; boiler, 8 ft. long and 51 ins. diameter; speed, 9 miles per hour, light. The tug *Spalpeen* was a general tender for the dredge, and also placed the gravel scows ready for dumping.

As at Stony Point, the dredge lay at anchor, in working position, throughout the week, and on Sundays was towed to shelter, behind the completed Stony Point breakwater. After September 18th, 1899, the dredge was towed to shelter behind the partially completed South Harbor breakwater every night.

Coal was brought from Buffalo on a small deck scow, provided with derrick and hoisting engine, and was transferred to the dredge in the evening by men who had been dumping gravel scows during the day.

The daily routine on the dredge was as follows: Men rise at 4.30 A. M.; dredge begins work at 5.00; breakfast, 6.00 to 6.30; dinner 12.00 to 12.30; supper, after finishing work, at 7.00 P.M.

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One of the main cables, on the starboard side, was in use for nearly a year, and was finally taken off because of general breaking and pulling apart. The work during 1899 was harder on the clam, apparently because of getting closer to and striking the smooth rock bottom, which made it necessary to repair continually. The dump scows were kept in much better condition than during previous seasons.

Material.—Most of the material dredged was a moderately stiff red clay, mixed with some blue clay, which, in some places, seemed somewhat harder to dig than in others. Overlying this clay was a layer of sand, perhaps 1 or 2 ft, thick. Underlying the clay, next to the rock, was a layer of hard blue clay, mixed with broken stone, or gravel, and, in places, there were a good many large boulders. The thickness of the layer next to the rock varied greatly. In some places it was so great that nearly a scowload was dredged from a small area, but for a good portion of the trench it was very thin, so that the rock was dredged off quite clean.

Dumping Grounds.—The dredged material was dumped in front of the lake face of the Stony Point breakwater, up to May 10th, 1899, after which only the last scow each day was dumped there, and an occasional scow during the day, in case of necessity. It was dumped

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The trench was completed on October 16th, 1899.

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A-frame and boom	15	"	15	"
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Meals	147	"	10	"
Fog and rain	6	"	15	"
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Hoist cables	24	"	53	"
Boilers	1	"	05	"
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Repairs to scows	14	"	51	"
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Waiting for tugs	9	"	37	"
Holidays, etc	42	"	53	"
Total	1 155	"	50	"

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1898.	h. m.	h. m.												
October.....	91 00	158 00	20¾	12	82	316.4	1.11	25 945	285	4.38	3.81	1 250	3 062	354
November.....	54 45	197 15	21	12	53	286	1.03	15 173	277	2.61	6.07	722	2 834	362
Season of 1898..	145 45	355 15	41¾	12	135	304.6	1.08	41 118	282	3.49	4.95	985	3 062	362
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May.....	190 37	131 23	23	14	166	322.2	1.1	53 494	280.6	8.3	2.7	2 325.8	4 621	369
June.....	232 11	131 49	26	14	191	335.2	1.2	64 022	275.7	8.9	2.8	2 462.4	4 318	346
July.....	211 40	152 20	26	14	180	306.3	1.2	55 138	260.4	8.1	1.6	2 120.7	4 001	264
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assistance came from the largest harbor tug in Buffalo, and the dredge was towed to shelter. Fortunately, little damage had been done.

Work for the season of 1899 was resumed on the trench on May 5th. The ranges suspended from wire cables were abandoned, and piles were driven instead, back ranges being erected on the Stony Point breakwater.

The method of dredging was as follows: A lake-side cut, about 100 ft. long and 35 to 40 ft. wide, was first made, then the dredge was shifted to the middle and worked forward the same distance, then shifted to the harbor side and worked backward, as on the lake side, thus making three parallel cuts. Several hundred feet of trench having thus been excavated, the dredge was moved to the point of beginning and the bottom of the cut thoroughly cleaned up.

After the first crib on the South Harbor Section had been placed in position it was used for the emplacement of the back ranges. The longitudinal location of the dredge was determined by measurement from fixed piles, as on the Stony Point Section, and also from fixed spar buoys, set to one side at right angles.

Three steel scows were used to transport the excavated material, and one wooden scow was used for a few days.

The general dimensions of the tug *Shaughraun*, used in towing the dredged material to the dumping grounds, off the mouth of Smoke's Creek, are: Length, 54 ft.; beam, 14 ft.; draft, 6 ft.; gross tons, 29; net tons, 14; iron hull; wheel, 54 ins.; engines, 12 x 15-in. cylinders; boiler, 8 ft. long and 51 ins. diameter; speed, 9 miles per hour, light. The tug *Spalpeen* was a general tender for the dredge, and also placed the gravel scows ready for dumping.

As at Stony Point, the dredge lay at anchor, in working position, throughout the week, and on Sundays was towed to shelter, behind the completed Stony Point breakwater. After September 18th, 1899, the dredge was towed to shelter behind the partially completed South Harbor breakwater every night.

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The quantity of material excavated during the season of 1899 was 316 343 cu. yds., which, at 18 cents per cubic yard, cost $56 941.74.

Some figures, as to the cost of this work to the contractor, may prove of interest. As far as known, the wages paid by the contractor during the season of 1899 were as follows:

Dredge runner	one	at	$90.00	per month.
Second dredge runner	"	"	35.00	" "
Fireman	"	"	35.00	" "
Deckhand	"	"	35.00	" "
Greaser	"	"	30.00	" "
Watchman	"	"	30.00	" "
Deckhands	seven	"	30.00	" "
Cook	one	"	30.00	" "
Cook's helper	"	"	15.00	" "

For working overtime the men received 15 cents per hour, the runner 30 cents per hour. The supplies for board cost $12 per month, per man.

From a careful record of the coal consumed, the quantity per 100 cu. yds. of material excavated was found to be 0.31 ton, but 0.35 ton is assumed for computations. Bituminous coal was used, and cost $1.50 per ton. The cost of the siphoning-out scow *Faugh-a-Ballagh* was:

One man, per month	$40.00
Coal, 20 tons at $1.50	30.00
Total	$70.00

Half the superintendent's wages ($125.00 per month) was charged to the dredge, the other half to gravel filling			$62.50	per month.
New cables			100.00	" "
Oil, dope, waste, etc.			20.00	" "
Blacksmith's shop			175.00	" "
Lines, cables, etc			40.00	" "
Miscellaneous expenses			50.00	"
Yard expenses			100.00	" "
Ranges and piles for the season.	12 piles	at	$6.00	$72.00
Driving	12 "	"	12.00	144.00
Cross-ranges,	10 "		2.00	20.00
Back-ranges, piles, etc				20.00
				$256.00

Small tugs, coaled	$20.00 per day.
Larger " "	25.00 " "
Large " "	30.00 " "

The assumed value of the plant is as follows:

Clam-shell dredge, *Fin MacCool*	$60 000.00
Steel dump scow, *Protective Policy*	12 000.00
" " " *Gold Standard*	10 000.00
" " " *Cuba Libre*	10 000.00
Total	$92 000.00

Annual depreciation, 10%; and interest, 6%; total, 16%, and, for one year, $14 720.

ESTIMATED COST.

Board	$980.34
Coal	1 660.80
Siphoning scow	369.24
Superintendence	329.67
Cables, main	527.49
Lines, ropes, etc	210.99
Blacksmith's shop	923.11
Yard expenses	527.49
Tugs	5 830.00
Range piles	256.00
Miscellaneous	263.74
Wages	2 823.14
Total,	$14 702.01
Depreciation and interest	14 720.00
Total	$29 422.01

Cubic yards excavated = 316 343

Cost per cubic yard $= \frac{\$29\,422.01}{316\,343} = \$0.09\frac{30}{100}$.

Operating expenses $= \frac{\$14\,702.01}{316\,343} = 0.04\frac{64}{100}$.

Interest and depreciation $= \frac{\$14\,720.00}{316\,343} = 0.04\frac{65}{100}$.

Trench Filling.—The filling of the trench with gravel was begun on May 18th, 1899, on which date five scowloads, containing 2 072 cu. yds. of gravel, were deposited. Most of the gravel was dredged

from the bed of the Niagara River, loaded in dump scows and then towed up the rapid current of the river, by the tugboat *Charles F. Dunbar*, built especially for this work. This tug towed the loaded scows to the head of the river, from which point they were towed to the work by a smaller tug, dumped and taken back, the larger tug towing the empty scows down the river. The average day's work was five scows, each with an average load of 465 cu. yds.

The supply of gravel from this source being insufficient for the proper progress of the work, the contractors were allowed to obtain gravel from the bed of Lake Erie, just off the shore in the vicinity of the sand-catch pier, and began digging there on July 3d, 1899. Work was suspended on July 10th, 1899, after taking out fifteen scowloads, or 3 858 cu. yds. The gravel obtained here was rather fine, occasionally with some silt, and was not as good as that from the Niagara River. For this reason, it was deposited in the deepest part of the trench.

The length of the South Harbor Section having been curtailed, as before stated, the contractors were anxious to complete it before the close of the season, and they were again allowed to dig sand near the sand-catch pier. Accordingly, a ladder (or elevator) dredge began work on September 1st, 1899, and continued through September and October, 1899. Owing to the accumulation of silt at places, there was much trouble in obtaining proper material. As before, it was placed as low down in the trench as possible.

The cost of 321 695 cu. yds. of filling, at 13 cents, was $41 820.35.

Rubble Foundation.—The foundation for the timber cribs was built in the same manner as that for the Stony Point Section, except that more stone was deposited by dump scows, a difference in the conditions allowing this to be done. The lake face of this breakwater was also rip-rapped to a greater height above the lake bottom, which accounts for the larger quantity of stone, as compared with the Stony Point Section.

The cost, up to December 15th, 1902, was as follows:

Rubble from United States....	25 678.5 tons, at	$0.80	=	$20 542.80
" " Canada.....	87 907.8 " "	0.75	=	65 930.85
" " Canada.....	12 579 8 " "	0.72½	=	9 120.36
Total.....	126 166.1			$95 594.01

Timber Cribwork.—The timber-crib breakwater, which is part of the project of the extension to Stony Point, adjoins the stone breakwater on the south, being a prolongation of the latter, with the exception that, owing to the different cross-sections of the two structures, the axes are not coincident, although parallel.

The breakwater is 2 739 ft. long, measured along the lake face. It consists of sixteen cribs, one of which is 60 ft. long, 36 ft. wide and 22 ft. deep, and is placed at right angles to the axis of the breakwater, projecting 24 ft. beyond the general harbor face of the work, thus forming an L, to be used as an emplacement for a lighthouse, protecting the South Harbor entrance.

The remaining fifteen cribs are each 180 ft. long, 36 ft. wide and 22 ft. deep, differing in this respect from the Stony Point breakwater, where the cribs are each 60 ft. long, with the exception of one shallow crib, 120 ft. long.

The 180-ft. cribs are composed of three grillage bottoms, each 60 ft. long, 36 ft. wide and 4 ft. high. These bottoms are bolted together firmly at each of the two joints, by seven 1¼-in. screw-bolts, 26½ ins. long, making a composite grillage bottom 180 ft. in length. The remaining eighteen courses are then laid up in the usual manner, great care being taken to break joints properly. The arrangement of the cross- and longitudinal- ties, and vertical posts, was identical with that of the 60-ft. cribs. There was no difficulty in sinking these long cribs; in fact, they were placed and sunk more readily than the shorter ones, and an almost absolute alignment was obtained. A decided advantage over the shorter cribs is the obliteration of two joints, which is quite a consideration.

Subsequent experience, however, demonstrated that these cribs should have been built with at least two solid transverse bulkheads, or, better still, with five, one for every 30 ft. Such bulkheads would have resisted the tendency of the long cribs to "warp" at the top, due to the buffeting of heavy storms.

The first of these 180-ft. cribs, designated as Nos. 48–49–50, was begun early in November, 1898. At the close of the season, December 9th, 1898, this crib had been built nine courses high.

Work was resumed on May 4th, 1899, and the crib was sunk in position on August 14th, 1899, forming the first 180-ft. crib of the substructure of the South Harbor Section. Crib No. 47, known as the L-crib, was sunk on July 20th, 1899.

The 180-ft. cribs contain the following quantities:

Hemlock						233 328	ft., B. M.
Pine						41 304	" "
Total						274 632	" "
Screw-bolts	171	1¼ x 37	ins.	at	19.51 lbs.	3 336.21	lbs.
"	472	1¼ x 26½	"	"	15.85 "	7 481.20	"
"	44	1¼ x 25	"	"	15.33 "	674.52	"
"	8	1¼ x 19	"	"	13.25 "	106.00	"
Drift-bolts	1 620	1⅛ x 32	"	"	9.01 "	14 596.20	"
"	1 856	1⅛ x 24	"	"	6.76 "	12 546.56	"
"	462	½ x 12	"	"	0.85 "	392.70	"
Total						39 133.39	"

The weight of the screw-bolts includes one nut and two washers with each bolt. The washers are 5 ins. in diameter and ½ in. thick.

The season of 1899 was one of great activity. Nine 180-ft. cribs were built and sunk and the superstructure completed over them. In addition, five 180-ft. cribs were built nineteen courses high, which included all the hemlock timber; another was built six courses high. At the close of the season 1 682.2 ft. of timber-crib breakwater had been completed.

Tifft Farm Framing Yard.—During the summer of 1898 the contractors installed two machines to lessen the labor of framing, a gaining machine and a tie-head machine, both manufactured by the Lake Shore Iron Works, of Marquette, Mich., for the Holley Manufacturing Company. They were housed in a building called the mill.

The mill was a wooden building, near the middle of the framing yard, just off the construction dock, 36 ft. wide and 60 ft. long. The boiler-house, 14 x 28½ ft., was at one end of the mill. The building also contained a butt-off machine, operating a 30-in. circular saw. The engine-room, 13½ x 15½ ft., was in one corner of the mill, and contained a Westinghouse engine. Adjoining the engine-room was a room, 12 ft. long, containing a Westinghouse air compressor. The air tank was outside of the mill.

Adjoining the air-compressor room there was an 8 x 12-ft. tool-room. In the central part of the mill were rollways on which the

timber was carried from the circular saw to the gaining and tie-head machines. A derrick, near the boiler-house, handled the timber on a runway, carrying it to the circular saw for squaring up. Outside the mill and just off the framing machines were two other rollways on which the framed timber was handled.

The manipulation of the timber at the yard and mill was as follows: The timber was dragged to the mill by horses. As a rule, there were two teams most of the time. It was delivered at the west end of the mill, squared off by a carpenter, and then hoisted by a small hand-derrick and placed on a runway on which it was propelled to the butt-off machine, where a circular saw squared the ends. The number of the stick, indicating its position in the crib, was marked on its end, and it was then passed over the rollway to the gaining machine, which cut the gains. The timber was then passed out of the mill on the adjoining runway, where a carpenter removed any remaining imperfections, caused by the varying thickness of the timber. It would have been a great advantage had the timber first been run through a planer or sizing machine, as is the practice on some other works.

The cross- and longitudinal- ties were manipulated in the same manner as the wall timbers, except that, instead of going to the gaining machine, they were run to the tie-head machine. After passing through the latter the stick was ready to put in the crib. The tie-head machine cuts two tie-heads at one time, of course on two different sticks. After the timber was framed it was loaded on small cars, running on a 3-ft. track, and taken to the dock, sorted and placed in the work. On the dock it was handled by derricks to the crib being built.

Obviously, the crib bottoms were constructed first. They were built on launching ways at the water's edge just east of the construction dock. The timber was handled by a derrick located between two platforms on which it was stored.

In building the grillage bottom great care was taken to make it perfectly square. This was usually done by measuring the calculated diagonal with a steel tape. After three courses had been placed and fastened together by screw-bolts, the vertical posts were put in and the bottom was ready for launching.

After three cribs had been launched they were bolted together and

the composite structure towed in front of the construction dock, where the remaining courses were fastened in place.

For boring the bolt holes the contractors used a "Little Giant" pneumatic boring machine, made by the Standard Pneumatic Tool Company, of Chicago, Ill.

A 60-ft. crib bottom was launched about every four days; and a 180-ft. crib was built nineteen courses high about every two weeks.

Superstructure.—After the cribs had been sunk and filled with stone, at least fourteen days were allowed for them to fully settle upon their foundation before the building of their superstructure was commenced.

This superstructure is continuous over the cribs. On this section it covered three 180 ft. cribs, making sections each 540 ft. in length, except the first section, which also covered the L-crib, making it 576 ft. long. These are the theoretical lengths, the actual length of a section being somewhat more, owing to the impossibility of making actual contact of the cribs. Consequently, there are five separate sections, one of ± 576 ft. and four of ± 540 ft. each, making a total length of 2 739 feet.

The superstructure was built as follows: The cribs were first leveled to the required grade above mean lake level, either by building up with timber when too low, or by adzing down when too high. The lake side was always kept about 4 ins. higher than the harbor side, to allow for settlement, the greater weight being on that side.

The side-wall timbers were then placed and drift-bolted. The first course in each set, known as the receiving course, had all been squared and the gains cut at the framing yard. The ties were then placed in position and the so-called covering course put on, this course being framed on the breakwater site. The other courses followed in regular sequence until the top was reached, the proper bolts being driven as the work progressed. The stone filling was generally put in as the timber work advanced, although there were exceptions, as the rubble was sometime slow in arriving. The decking was the last work to be done.

A small deck scow, rigged with derrick and hoisting engine, handled the timber on the work.

The rubble was transferred from deck scows and canal-boats by one of the floating derricks used in the adjacent rubble-mound section.

The building of the superstructure was very expeditious. Section No. 1, 577.1 ft. long, was completed on October 31st; Section No. 2, 540.4 ft. long, on November 30th; and Section No. 3, 540.7 ft. long, on December 19th, 1899.

Several severe storms occurred during the early part of December, 1899. The gale of December 12th, was especially severe, and caused considerable damage to Sections Nos. 1 and 2. The damage was confined to the parapet or upper deck, and seventy ties were broken. These were 12 x 12-in. ties, 12 ft. long, over all, and 10 ft. between supports, spaced at 5 ft. from center to center. They failed by breaking in the middle. The breaking of these ties also caused the failure of some of the 3-in. decking, which was placed at right angles to the ties and was supported by them. Undoubtedly, the damage was caused by the impact of the falling water of the high seas, which rose to a great height upon striking the vertical face of the lake side of the breakwater. Section No. 3 was in course of construction at the time of the gale, and, in order to strengthen the unfinished portion of the parapet, a 12 x 12-in. timber was placed longitudinally with the axis in the center of the parapet and resting upon the last but one series of ties, thus affording an additional support for the upper ties and deck.

The completed timber-crib breakwater withstood the winter of 1899–1900 admirably, except that there was some little movement of crib Nos. 57–58–59, due to the enormous ice pressure.

Work for the season of 1900 was commenced on May 17th. A slight change was made in the parapet of the remaining part of the timber work, which consisted in spacing the top row of ties at 3 ft. 4 ins. from center to center, instead of at 5 ft., as called for by the original plans. A 6 x 12-in. longitudinal timber was also placed under these ties as an additional support. These changes were made on account of the weakness developed in the parapet laid during the season of 1899.

A very severe gale occurred on September 11th and 12th, 1900, following closely upon the hurricane which wrecked the City of Galveston, Tex., and did considerable damage to the completed work. The parapet suffered most, although more or less damage was also done to the middle deck. The damage consisted in the breaking of the ties, the resulting deformation of the decking, and the breaching of the upper timber walls.

Some damage was also done to the work under construction on Section No. 5, which was repaired at once by the contractors. The

remaining part of the unfinished work was strengthened by the addition of longitudinal timbers, blocks and struts. Steps were taken at once to repair the damaged work, and a large quantity of timber was accumulated for this purpose. A working plant and force was organized, when, on November 21st, 1900, while the repair work was being prosecuted, another gale occurred. This gale was of unusual violence, the wind blowing from the west at the rate of 80 miles an hour.

Considerable damage was done to the superstructure of the completed work, and more especially on Sections Nos. 1 and 2; on the former, 360 ft., and on the latter, 540 ft., were razed almost to the water's edge. Sections Nos. 3 and 4 were also badly damaged, the entire middle deck on the latter being razed to the banquette level. Where the ties had been spaced at 3 ft. 4 ins. from center to center, and extra longitudinal timbers inserted, the parapet withstood to some extent the effect of the gale. On Section No. 5, about 150 ft. of the work was badly damaged, the remainder standing very well. The substructure cribs suffered no damage.

The cost of the cribwork was as follows:

Cribwork, 2 763 lin. ft. at $92.37	$255 218.31
Mooring cleats, 15, " 6.00	90.00
Mooring posts, 15, " 36.00	540.00
Extra work on ⌊ at south end	725.96
Additional timber and bolts, strengthening parapet	1 367.66
	$257 941.93
Deduct for 52 636.2 tons Canadian filling stone, at 5 cents	2 631.81
Total cost	$255 310.12

Table No. 22 shows in detail the various quantities of material used in the construction of the South Harbor timber-crib breakwater up to December 15th, 1902.

The following statement gives the cost (to the contractor) of labor employed in building the timber cribs and superstructure of parts of the Stony Point and South Harbor breakwaters for the working season of 1899, being from May 1st to December 19th, inclusive.

The quantity of hemlock placed in cribs during the season was 3 207 144 ft., B. M., being wholly used in the South Harbor Section. All the hemlock used in the cribs, and also the pine posts and an occasional course of pine, were framed and placed at Tifft Farm.

TABLE No. 22.

Number of section	Number of cribs.*	Timber.		Screw-bolts, in pounds.	Drift-bolts, in pounds.	Spikes, in pounds.	Number of cleats.	Number of posts.	Foundation stone, in tons.	Filling stone, in cubic yards.
		Hemlock, in feet, B. M.	Pine, in feet, B. M.							
1-5	16	3 582 504	2 846 085	178 956	653 479	33 990	15	15	126 166	94 051

* Fifteen cribs, each 180 ft. long, one crib, 60 ft. long, set cross-wise.

The quantity of pine used in the cribs and worked at Tifft Farm was 97 824 ft., B. M., making a total, of hemlock and pine, of 3 304 968 ft., B. M.

The cost of labor on this work for the season averaged $1.90½ per 1 000 ft., B. M.

All the hemlock, and the major part of the pine, was framed by machinery, one machine cutting the gains of the side- and end-wall timbers and another cutting the tie-heads fitting into these gains.

The quantity of timber worked by the mill, and handled in the yard, for the season was:

Hemlock	3 207 144 ft., B. M.
Pine	2 163 556 " "
Total	5 370 700 " "

The figures include some of the longitudinals and short ties which required no framing, also the covering courses of the superstructure, which were squared by the mill, but the gains were cut by hand on the work. On a basis of all the timber handled during the season, viz., 5 370 700 ft., B. M., the cost per 1 000 ft., B. M., was 92 cents. The handling included unloading the timber from cars, piling it, transporting it to the mill and from the mill to the dock and to scows.

The cost per 1 000 ft., B. M., for this handling was 48½ cents. The quantity of timber framed and placed in the work at both breakwaters during the season was as follows:

Stony Point: Cribs	31 968		
Superstructure,	397 831	429 799 ft., B. M.	
South Harbor: Cribs	308 856		
Superstructure,	1 327 077	1 635 933 "	"
Total		2 065 732 "	"

The average cost of doing this work was $3.23 per 1 000 ft., B. M.

The total quantity of timber handled, framed and placed during the season was 5 370 700 ft., B. M., at an average cost of $3.82 per 1 000 ft., B. M., the handling and driving of bolts being included.

The average run of timber per linear foot of standard section is 1 526 ft., B. M., for the cribs and 772 ft., B. M., for the superstructure, or a total of 2 298 ft., B. M.

At the rate stated, $3.82, the cost of labor per linear foot of completed timber-crib breakwater was $8.78. This, of course, does not include the stone filling.

The weight of bolts and spikes of all kinds used per linear foot of breakwater was 217.4 lbs. for the cribs and 91.2 lbs for the superstructure, a total of 308.6 lbs.

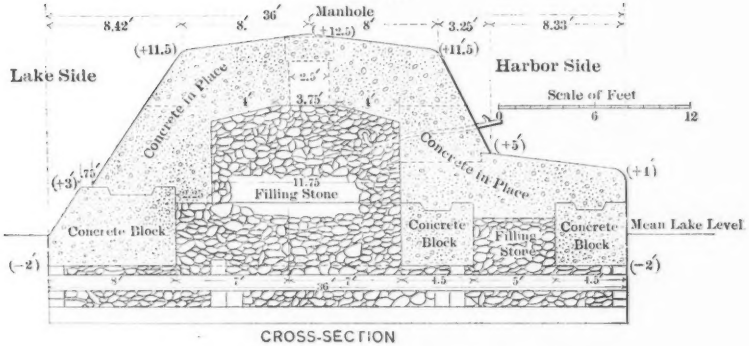
The rubble filling per linear foot required for the cribs was 27.2 tons and for the superstructure 11.0 tons, a total of 38.2 tons.

The wages paid at the Tifft Farm framing yard were as follows:

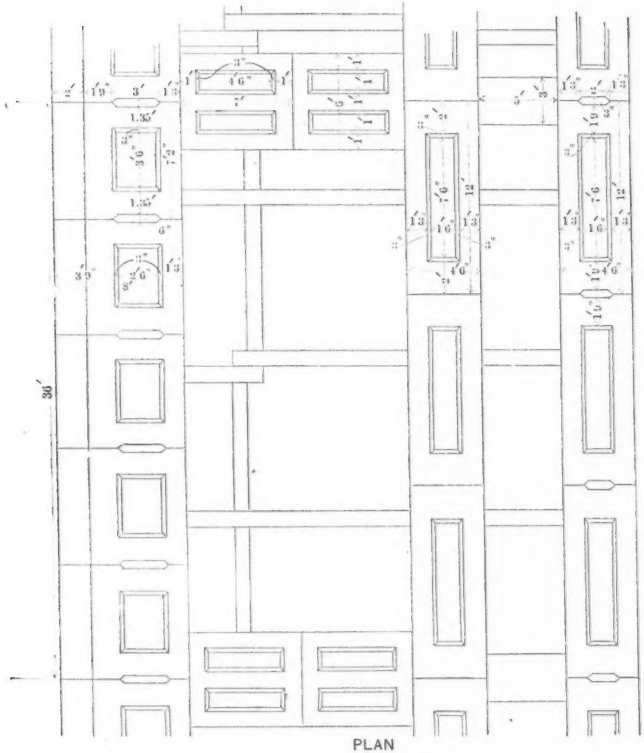
Superintendent	$100.00	per month.
Time keeper	65.00	" "
Watchman	50.00	" "
On cribs:		
Foremen	0.22½	per hour.
Carpenters	0.20	" "
Laborers	0.15	" "
In yard:		
Foreman	60.00	per month.
Laborers	0.15	per hour.
Teams and drivers	0.35	" "
Mill:		
Foreman	75.00	per month.
Engineman	65.00	" "
Machine men—framing	0.25	per hour.
Carpenters	0.20	" "
Laborers	0.15	" "
Team and driver	0.35	" "

Concrete Superstructure.—Soon after the demolition of the timber superstructure of the South Harbor Section, several plans for a new

CONCRETE SUPERSTRUCTURE
OF THE
SOUTH HARBOR BREAKWATER,
1901-1902



CROSS-SECTION



PLAN

FIG. 25.

superstructure were considered, and it was finally decided to rebuild it with a concrete shell and fill the interior with rubble.

The necessary plans and specifications were at once prepared, and on January 25th, 1901, proposals for building 1 800 ft. of concrete superstructure were invited, to be opened on February 25th, 1901. In response, seven bids were received, all of which were rejected.

New bids for the work were asked on March 21st, 1901, to be opened April 5th, 1901. On this date four bids were received, and that of the Buffalo Dredging Company, of Buffalo, N. Y., being the lowest, the work was let to this firm on April 10th, 1901.

The type of structure adopted, Fig. 25, consists of three main parts, viz.:

1.—Semi-submerged large concrete blocks, serving as a foundation and resting upon the stone-filled timber cribs, with their bases 2 ft. below mean lake level. The lake- and harbor- face blocks are provided on their abutting faces with joggle channels, and, in addition, these and all other blocks have sunken-panel recesses on their top faces, 6 ins. deep. The blocks are made in the open, and placed in position afterward.

2.—Concrete *in situ*, comprising the banquette deck, parapet walls, and parapet deck, founded on the concrete blocks.

3.—The rubble filling.

The superstructure consists of isolated sections, each practically 36 ft. long, which linear dimension was determined by making five sections for each 180-ft. crib.

Each section is made up of: Five lake-face blocks, trapezoidal in section, 7.2 x 8 x 5 ft., each containing 9.45 cu. yds., and weighing, approximately, 18.9 tons; three harbor-face blocks, rectangular in section, 12 x 4.5 x 4 ft., containing 7.64 cu. yds., with an estimated weight of 15.28 tons; three interior-wall blocks, of the same dimensions as the harbor-side blocks, but without joggle channels at the ends, making their volume 7.75 cu. yds. and their weight 15.5 tons.

These blocks are laid in three parallel rows, the space between the lake-side and interior-wall blocks is 14 ft. wide, that between the harbor-side and interior-wall blocks is nominally 4 ft., but, generally, slightly more. In addition, there are two parapet cross-wall blocks, each 7 x 6 x 4 ft., containing 6 cu. yds., and weighing 12 tons. These blocks connect the lake-face and interior-wall blocks; they are spaced



FIG. 1.—SOUTH HARBOR SECTION. VARIOUS STAGES OF CONCRETE SUPERSTRUCTURE. 1901.



FIG. 2.—SOUTH HARBOR SECTION. COMPLETED CONCRETE SUPERSTRUCTURE. 1901.

at 36-ft. centers, and form the foundation for every two adjacent cross-walls. There are also banquette cross-wall blocks, 4 x 3 x 4 ft., also spaced at 36-ft. centers.

The blocks rest partly on the crib timbers, that is, the face walls, and on the ties where they occur, but most of their area is on the rubble filling.

The joggle channels, of the abutting faces of the lake-face and harbor-face blocks, were filled with concrete after the blocks had been placed in juxtaposition, thus tying them together and preventing any lateral movement. The enclosure formed by the blocks was filled with rubble.

These blocks served as a foundation for the banquette deck on the harbor side, and for the parapet walls on the lake side, all built of concrete *in situ*.

After the parapet walls had been formed, the enclosed space was filled with rubble, the parapet deck resting partly on the walls and partly on this stone filling.

The theoretical quantities contained in each 36-ft. section are as follows:

Blocks.

Lake-face blocks	5	at	9.68	cu. yds.	48.40 cu. yds.
Harbor-face blocks	3	"	7.75	" "	23.25 " "
Interior-wall blocks	3	"	7.75	" "	23.25 " "
Parapet cross-wall blocks	2	"	6.00	" "	12.00 " "
Banquette cross-wall block	1	"	2.22	" "	2.22 " "
Total blocks	14				109.12 " "

Concrete in place.

Banquette deck	54.55 cu. yds.
Parapet walls	81.04 " "
Parapet deck	99.19 " "
Total	234.78 " "

All the blocks were made on a construction dock, erected especially for this purpose near the breakwater site. It consisted of ten parallel rows of piles, closely driven, and capped by 12 x 12-in. timbers, on top of which was laid a 2-in. planed plank floor 32 ft. wide and 277 ft. long.

The mixer, hoisting engine and derrick were in the central part of the dock. Running the entire length of the same were two 20-in. elevated railroad tracks. The moulds in which the blocks were cast

were in four rows on either side of the tracks. There were, in all, seventy-five moulds, thirty for the lake-face, thirty-four for the harbor-face and interior-wall, and eleven for the parapet cross-wall, blocks. The banquette cross-wall blocks were made in place on the breakwater. The moulds had removable sides and ends, adjusted so as to be taken apart readily, which was done as soon as the blocks had become sufficiently hard.

A 4-ft. cubical mixer of the ordinary type was used. The broken stone was brought to the work in canal-boats, and for the transportation of the cement, sand and gravel, a remodeled dump scow was used, the pockets of which were utilized for storage purposes.

The composition of the concrete was as follows:

Lehigh Portland cement	1 part.
Screened gravel	1 "
Sand grit	2 parts.
Unscreened broken limestone	4 "

The unit of measurement was a bag of cement, which was considered to contain 0.9 cu. ft.

The concrete was made in batches containing four bags of cement. The gravel and sand grit were measured in wheel-barrows containing the equivalent of four bags of cement, or 3.6 cu. ft. The broken stone was measured in steel buckets, holding 21.6 cu. ft., in which the required quantity, viz., 14.4 cu. ft., was indicated by a mark. These steel buckets had been made for use with the 5-ft. cubical mixer in which was made the concrete to be placed *in situ*. In that work the batches contained six bags of cement, and, consequently, 21.6 cu. ft. of broken stone.

In making the smaller quantity, it would have been better had the bucket contained a false bottom, as it would have caused less strain on the inspector in trying to keep the stone down.

The concrete was made wet, from 2 to 2.5 cu. ft. of water, being used in a batch. It was found that one batch of concrete made about 20 cu. ft. when rammed.

The characteristics of the various materials, as obtained from tests, were as follows: 1 cu. ft. of sand grit contained 0.47 cu. ft. of fine gravel, the grains of which ranged from $\frac{1}{8}$ to $\frac{1}{4}$ in., and 0.59 cu. ft. of sand, the respective weights being 47.2 and 59.3 lbs., equivalent to about 100 lbs. per cu. ft. for the screened, or 106.5 lbs. for the combined, materials. One cu. ft. of gravel contained 0.80 cu. ft. of gravel,



FIG. 1.—JUNCTION OF STONE BREAKWATER WITH SOUTH HARBOR TIMBER SECTION. 1902.

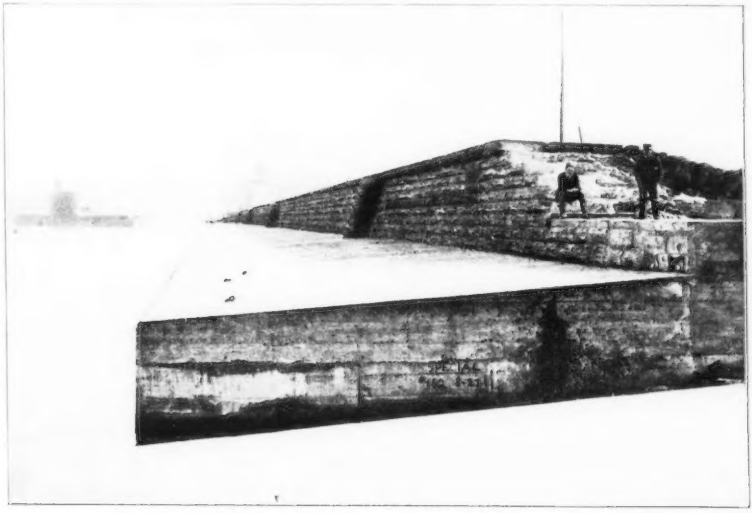


FIG. 2.—SOUTH PIER. ENTRANCE TO BUFFALO RIVER. STONE MOLE, BUILT 1826–1839. CONCRETE BANQUETTE. 1901.

generally ⅜ in. in size, and 0.29 cu. ft. of sand, the respective weights being 81.5 and 29.2 lbs., again indicating closely 100 lbs. per cubic foot for the screened, or 110.7 lbs. for the combined materials. The broken stone showed 0.63 cu. ft. of coarse and 0.33 cu. ft. of fine stone and 0.11 cu. ft. of dust, weighing respectively 53.8, 30.4 and 11.0 lbs. for the screened, or 95.2 lbs. for the combined materials. This latter weight, however, is not correct for the broken stone as used in the work, because, in a box containing only 1 cu. ft., it is extremely difficult to shake down the stone as can be done in a larger receptacle. The actual weight of the unscreened broken stone was 101 lbs. per cubic foot. In these experiments the sand and gravel were sifted through a sieve containing 36 meshes per square inch. A ¾-in. sieve was first used for the broken stone, then the No. 36 sieve.

The concrete blocks were lifted by a large floating derrick, placed on deck scows, and carried to the breakwater. They were placed in the work by the same derrick. The plant for making the concrete *in situ* was installed in an old dismantled schooner, 137.3 ft. long, 26. 6 ft. beam, and 11.6 ft. deep.

A 5-ft. cubical mixer was used. There were two hoisting derricks, one for lifting the ingredients from the scows to the mixer, the other to put the concrete in the work. The composition of the concrete *in situ* was the same as that of the concrete blocks, except that it was mixed in larger batches, the unit being six bags of cement, which produced 43.2 cu. ft. in each batch.

The concrete was made wet, about 3½ cu. ft. of water being used in each batch. About 28.5 cu. ft. of rammed concrete was made from each batch.

Three sets of forms were used for moulding the concrete *in situ;* one for the banquette deck, one for the parapet walls, and one for the parapet. The sheeting was of 3-in. stuff, spiked to a heavy framework. They were constructed so as to be taken apart readily and used repeatedly as long as they remained in proper condition.

The following is a *résumé* of the work of construction:

June 18th, 1901.	Commenced making concrete blocks.
July 10th, 1901.	First blocks set.
July 26th, 1901.	First mass concrete placed.
Nov. 18th, 1901.	Work for the season suspended.
April 14th, 1902.	Work for the season of 1902 resumed.
May 18th, 1902.	Work completed.

The cost of the concrete superstructure was as follows:

Old superstructure removed,	1 800.48	ft.,	at $12.00	$21 605.76
New timber	13 631	" B. M.,	" 100.00	1 363.10
Stone filling dredged	1 468	cu. yds.,	" 1.00	1 468.00
New stone filling	4 642	tons,	" 0.80	3 713.60
Concrete blocks	5 458.22	cu. yds.,	" 10.00	54 582.20
Concrete in place	11 807.23	cu. yds.,	" 9.40	110 987.96
Manhole covers	50		" 5.00	250.00
Mooring rings	25		" 55.00	1 375.00
Total cost				$195 345.62

or $108.49 per linear foot.

TABLE No. 23.—Cost of Extension of Buffalo Breakwater to Stony Point, up to December 15th, 1902.

Stone Breakwater.

Gravel	245 242 cu. yds.		
at 13 cents		= $31 881.46	
Rubble	667 799.2 tons,	= 527 282.57	
Capping stone	284 878.5 tons.	= 348 975.66	
			$908 139.69
(7 250 lin. ft. $125.26 per linear foot.)			

Stony Point Breakwater.

Dredging	206 861 cu. yds.		
at 18 cents		= $37 234.98	
Filling	193 383 cu. yds.		
at 13 cents		= 25 139.79	
Foundation stone	19 170.8 tons,	= 15 018.49	
*Timber cribwork	2 826.9 lin. ft.	= 200 031.86	
			$277 425.12
(2 802.9 lin. ft. $98.97 per linear foot.)			

South Harbor Breakwater.

Dredging	357 461 cu. yds.		
at 18 cents		= $64 342.98	
Filling	321 695 cu. yds.		
at 13 cents		= 41 820.35	
Foundation stone	126 166.1 tons,	= 95 594.01	
Timber cribwork	2 763 lin. ft.	= 255 310.12	
			$457 067.46
(2 739 lin. ft. $166.87 per linear foot.)			
			$1 642 632.29
Concrete superstructure (1 800.48 lin. ft.)			195 345.62
Total cost to date, exclusive of superintendence, office and other expenses			$1 837 977.91

*Includes $3 819.46 for repairs, on account of storms.

BREAKWATER TO PROTECT BUFFALO ENTRANCE TO BLACK ROCK HARBOR AND ERIE BASIN.

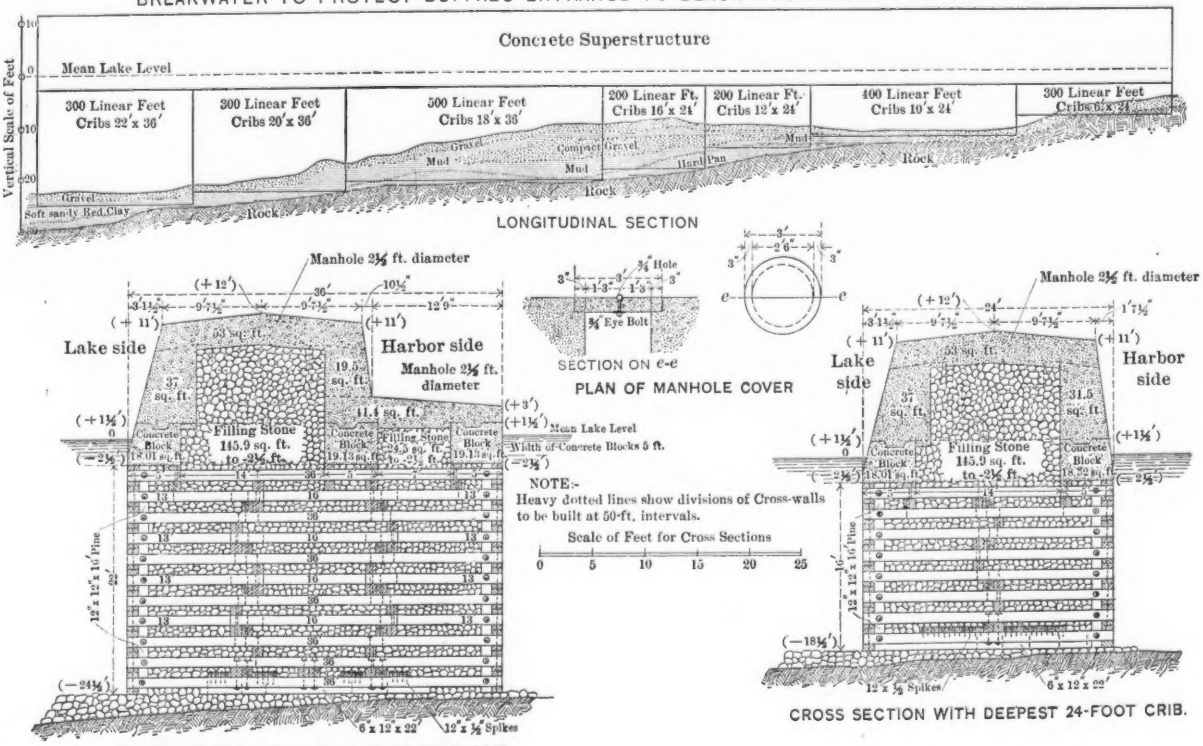


FIG. 26.

The North Breakwater.

This work comprises a breakwater, 2 203.4 ft. long, which covers and protects the entrance to the Erie Basin and Black Rock Harbor, between the Erie Basin Breakwater and the Bird Island Pier.

The substructure is timber cribwork, 1 101.9 ft. of which is 36 ft. wide, the remaining 1 101.5 ft. being 24 ft. wide. The depths vary from 22 ft. at the south end to 5 ft. at the north end. See Fig. 26.

On the axis of the structure the depths to rock ranged from 30 ft. to a little more than 5 ft., the stratum over the rock being gravel, sand, mud, and a clay of varying degrees of consistency. As the material overlying the rock did not furnish a stable foundation for cribwork, it was all dredged out and the deeper parts filled with rubble to an elevation of 22 ft. below mean lake level. In the shallower parts the cribs are fitted to the rock, as nearly as possible, and the irregularities corrected with rubble deposited where needed to level up the rock surface. On a foundation of this kind it was possible to construct at once a permanent concrete superstructure, no settlement being apprehended.

The superstructure is a shell of concrete from 3 to $5\frac{3}{4}$ ft. thick, filled with stone, founded on semi-submerged concrete blocks, resting on the cribs, the tops of which are sunk to $2\frac{1}{2}$ ft. below mean lake level.

The structure is similar to that built on the ice-breaker section of the old breakwater and that of the South Harbor Section.

As on other works forming Buffalo Harbor, unfavorable weather conditions hindered progress, and in two storms much damage was done to the uncompleted work. During the first, which occurred on September 11th and 12th, 1900, and is usually called the Galveston storm, the velocity of the wind was 80 miles an hour, and the water reached a level of 5.6 ft. above mean lake level. All the lake- and harbor- face blocks not covered by concrete were displaced, and one hundred and eighty-eight blocks were washed off the cribs. More than 1 600 cu. yds. of stone filling were also washed out. The storm of November 21st, 1900, also did more or less damage.

The work was done under the River and Harbor Bill of March 3d, 1899.

The contractor was J. B. Donnelly, of Buffalo, N. Y.; the work was started in August, 1899, and completed on June 4th, 1901.

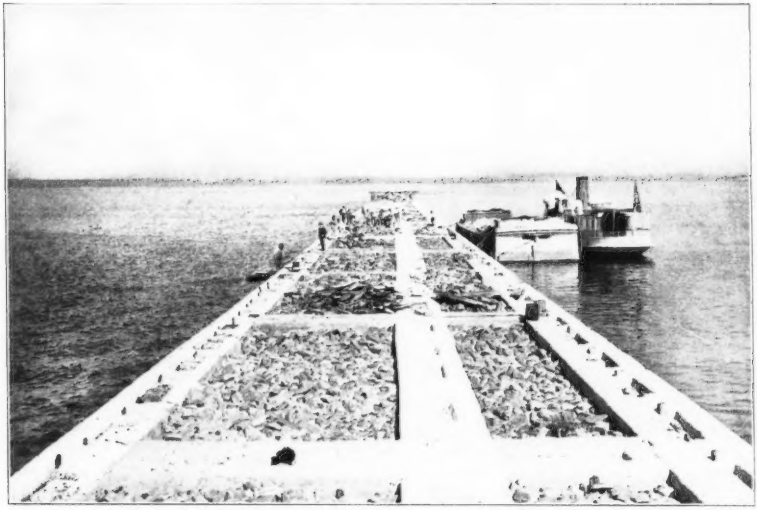


FIG. 1.—NORTH BREAKWATER. CONCRETE BLOCKS. FOUNDATION FOR MASS CONCRETE IN PLACE. 1900.



FIG. 2.—NORTH BREAKWATER. BANQUETTE MOULDED. SETTING LAKE-SIDE CONCRETE BLOCKS. 1900.

U OF M

TABLE No. 24. TOTAL COST OF THE NORTH BREAKWATER.

Trench excavation	41 657	cu. yds.	at	$0.20	$8 331.40
Rip-rap	7 133	tons	"	0.84	5 991.72
Foundation stone	9 325	"	"	0.69	6 434.25
Cribs, 22 x 36 ft	300	lin. ft.	"	62.00	18 600.00
" 20 x 36 ft	300	" "	"	56.00	16 800.00
" 18 x 36 ft	500	" "	"	48.00	24 000.00
" 16 x 24 ft	200	" "	"	30.00	6 000.00
" 12 x 24 ft	200	" "	"	24.00	4 800.00
" 10 x 24 ft	400	" "	"	21.00	8 400.00
" 6 x 24 ft	300	" "	"	15.00	4 500.00
Filling stone	13 640.9	tons	"	0.69	9 412.21
Concrete blocks	4 613.75	cu. yds.	"	7.10	32 757.63
Mass concrete	12 320.9	" "	"	5.65	69 613.08
Manhole covers	70		"	3.00	210.00
Mooring rings	12		"	50.00	600.00
Anchor bolts and plates	3 774	lbs.	"	0.10	377.40
Total					$216 827.69
Cost of recovering and replacing concrete blocks and stone filling washed from the breakwater by storms					6 000.00
					$222 827.69
Engineering and office expenses					13 450.41
Total					$236 278.10

CANADIAN QUARRY.

The quarry from which was obtained much of the rubble, and all of the capping stone, used in the extension to Stony Point, is located at Windmill Point, Ontario, Canada, on the north shore of Lake Erie, about 5 miles west from Buffalo.

The tract of land upon which the quarry is located contains about 80 acres, bordering on and lying south of the Grand Trunk Railway, having a frontage of about ¼ mile on the railway and a depth, toward Lake Erie, of about ½ mile. The land does not extend to the water front, and, in order to reach the latter, the contractors obtained in the beginning a right of way, 20 ft. wide, over the intervening property, which, later, they acquired by purchase.

The land is approximately level, and the stone was quarried from below the surface, the overlying earth being from 2 to 5 ft. in depth. The quarry was opened by removing this earth for a length of about 900 ft. and a width of about 50 ft. As originally laid out, the direction of the stripping was approximately east and west, but, after about 600 ft. of the rock had been uncovered, a pocket of earth, from 6 to 7 ft. in depth was encountered, so the direction was changed somewhat. The shorter section is 300 ft. long, and the angle between the sections is about 30 degrees.

After completing the stripping, tracks were laid along the south edge, and a line of derricks erected between the tracks and the stripping. The rock was then blasted out by heavy charges of dynamite, ranging in power from 30 to 50 per cent. The result of these heavy charges was the breaking up of the rock into very small fragments, making much of the material useless for breakwater work. Much of it, however, was used by the contractors for filling the cribs of their loading dock, ballasting track and other purposes.

Soon after commencing blasting, it was found that the strata at the eastern end of the quarry were thicker than those at the western end, the layers running from 2 to 5½ ft. in thickness. Blasting operations, therefore, were confined to the western end, the excavated material being used for rubble, while that at the eastern end was reserved for revetment and capping stone.

For the transportation of the stone, a 3-ft. narrow-gauge railway, with the necessary sidings and turnouts, was laid from the quarry to the loading dock, about a mile distant.

The approach to the dock is about 835 ft. long, and the dock, as originally built, consisted of a series of isolated timber cribs connected by stringers. The cribs are of hemlock, and are 20 ft. wide and 22 ft. long, their depths varying with the depth of the water, which, at the outer end, is about 14 ft. The cribs are filled with stone and are wide enough for two tracks. The spans between the cribs are 20 ft., and the track stringers, of which there are two under each rail, are 24 ft. long, 8 ins. wide, and 12 ins. deep.

Since the cribs were sunk, about 400 ft. of the approach has been filled in with débris from the quarry.

The loading dock proper, at the outer end, is about 365 ft. long, and consists of cribs placed end to end, with heavy rip-rap on the

west or seaward side. At the extreme end there is also an L-crib, serving as a protection.

There are two engine-houses, on separate cribs, and two loading derricks on the edge of the dock.

Originally, both flat cars and dump cars were used for carrying the quarried material. The flat cars were intended for carrying capping stone, and also for skips and boxes, which were loaded on the ground in the quarry, then hoisted to the flat cars by derricks, then transported to the loading dock and there unloaded by the derrick. When the dump cars were used, the material was loaded into skips by hand, and these were then unloaded into the dump cars by derricks, or, where the stones were of large size, they were loaded directly by the derricks.

In the beginning (the fall of 1897), the plant at the dock consisted of a stiff-leg derrick, operated by a hoisting engine, and two stationary loading chutes. In unloading rubble from dump cars, it was dumped into the chutes, from which it was allowed to run into the pockets of the scows. There was much difficulty in using these loading chutes, owing to the fluctuations in the level of the lake, the scows often jamming under them and causing more or less damage. The dump cars, also, were not especially adapted for carrying rubble, and it was soon evident that the loading and dumping of the skips was unnecessary labor, when they might as well be carried at once on a flat car and unloaded at the dock by derricks. The change was adopted, although it put twenty-five cars out of service.

In opening the quarry, a depth of 30 ft. below the surface of the ground was contemplated, but this depth was only reached at a few points, at the end of the working season of 1897. Soon after the opening of the working season of 1898, the quarry reached a depth of 30 ft. for a length of about 600 ft. A double track was then laid along the south face of the quarry at a height of 6 ft. above the bottom, the foundation of the tracks being the débris from the quarry operations. The derricks, which stood formerly at the top of the quarry, were removed to the bottom. An inclined plane was also built and used for drawing the loaded cars out of the quarry.

The rock quarried is a stratified limestone, dark gray in color, hard and brittle in texture and weighs about 166 lbs. per cubic foot. An analysis of the rock is given in Table No. 26. The courses dip to the east and get thicker as they are worked to the

north. The thickness of the different courses varies considerably in the length of the quarry. The stone is taken out in four ledges. At the west end the first ledge is about 10 ft. thick, and the first 150 ft. or so is shelly and only suitable for rubble, very few capping stone being quarried from it; in fact, very few capping stone are obtained from any of the courses in the first 150 ft. At the middle of the north side, or near the angle, the first ledge is about 12 ft. thick, and has a 3-ft. shell on top, which drops off at 150 ft. east of the angle. This shell is used principally for rubble. At the east end the first ledge is 8 ft. thick, with a 30-in. shell on top. The second ledge varies from 7 ft. at the west end to 10 ft. at the east end. The third ledge is more uniform, and is about 5 ft. thick. Under this is what is called the flint course. It is from 6 to 7 ft. thick at the west end, but at the east end little of it was quarried, as the grade of the bottom of the quarry rises for the incline located there.

The strata on the south side of the quarry are very much laminated, and, consequently, stone from that portion was only used for rubble. This class of material was quarried by blasting holes charged with dynamite, producing generally large, irregular-shaped fragments, which, when required, were reduced in size by "mud capping," which consists of placing two or three sticks of dynamite on a stone, covering with mud and firing.

When it was decided to make part of the breakwater extension to Stony Point a rubble mound, the question of procuring the large revetment and capping stone was paramount. The original estimate called for 220 000 tons of stone of this class, to be in blocks quite symmetrical in shape. This quantity of stone was equivalent to about 32 000 blocks, and, in place, would occupy an area approximately 300 ft. square and 30 ft. deep. It is extremely doubtful if a quarry which could furnish this quantity, within a limited time and at reasonable cost, could have been found in the immediate vicinity of Buffalo. The acquisition of the Canadian quarry, however, solved this problem successfully, and it can be safely said that there are few quarries equal to it, as far as concerns special adaptation to furnishing the required stone. These advantages consist mainly of three important items, namely, an excellent quality of stone, the thickness or depth of the ledges, and their normal or horizontal stratification.

In quarrying the large blocks of stone, the so-called Knox system

of quarrying was used. This system is the invention of Mr. John L. L. Knox (deceased), of Allegheny, Pa., and the main patent (No. 291 606) was granted on January 8th, 1884. This and other patents have expired, and have been open to free use since July 1st, 1902. The essential features of the Knox system consist in controlling and directing the force produced by the explosive, so as to make it break the rock in a prescribed line without injury to the standing rock. This is done by a blast hole of a peculiar shape, and a special method of tamping and charging it.

The shaping of the hole, the special tool to make it, the methods of charging and tamping, together with their combination, represent the special features of the system.

The practical methods of quarrying by this system varied somewhat in the different seasons. In the beginning, the blocks were quarried in irregular sizes. This was soon modified by making one dimension always 6 ft., this being the contract requirement for the depth of the "giant pavement," as it was termed in the specification. After the quarry had attained a depth of 30 ft., an approximately plane face had also been secured. A line of holes, 6 ft. from this face, was then drilled, loaded and exploded, producing a long block of stone of this width and of varying depth, depending on the thickness of the ledge. These blocks were then cut into parallelopipedons or cubical blocks. Later, the line of holes was drilled 12 ft. from the face.

The final practice, however, was as follows: The overlying earth was stripped off the rock for a width of 20 ft. or more. The face of the quarry was then worked in four stages. To work the first or top ledge a line of holes 18 ft. from the face was drilled. These holes averaged 4 ft. from center to center, and extended to within 6 ins. of the bottom of the ledge, in this case about 12 ft. deep. The number of holes for one shot varied from fifty to sixty-five, although many shots containing only from twenty-five to thirty holes were made. Where possible, the holes were made to start and end at cross-seams, so that the ledge could be moved out without being broken up.

Sargeant machine drills, operated by steam, were used. In starting a hole a 2⅜-in. drill was used, making a slightly tapering hole, 2 to 3 ft. deep, the drill then requiring resharpening. The second drill was from ⅛ to ¼ in. smaller than the first, and drilled about the

same depth, when a still smaller one was used, and so on, until the full depth was attained, the diameter of the last drill being generally $1\frac{5}{8}$ to $1\frac{3}{4}$ ins.

When the holes had reached the required depth, a reamer was used The face outline of this tool is in the form of a hexagon. Referring to Fig. 27, taken from the original patent specification, the sides, *c c*, are parallel, and are equal in length to the sides of a square inscribed within the circle of the cylindrical bore. This brings each of the corners, *d*, in contact with the surface of the bore, and thus guides the tool and insures the passage of the plane bisecting the grooves through the center or axis of the bore.

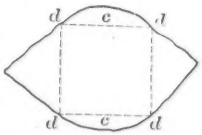


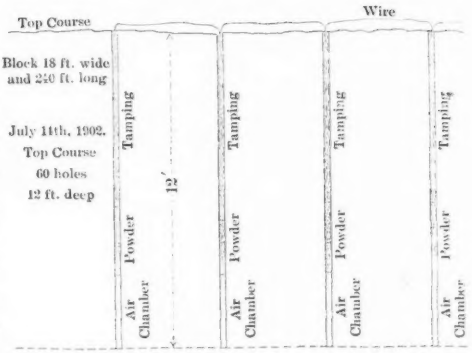
FIG. 27.

In practice, however, the central part of the reamer was made oblong instead of square, the width being generally 1 in. for all sizes used, and the long diameter being variable, depending on the size of the hole in which it was to be used. From Fig. 27 it is very evident that the object of the reamer is to cut two angular grooves lengthwise of the drilled hole. These grooves are located in the axis of the line of drill holes.

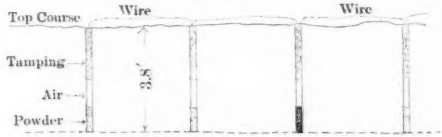
At first, there was more or less difficulty in guiding the reamers so that the grooves would be in proper position, or perpendicular. The square shank or stem was gripped by tongs or nippers, but, in driving, the tendency of the shank was to turn, thus making a twisted groove.

To obviate this, castings, about 4 to 6 ins. long, and fitting the top of the hole, were made. In these there was a square hole, in which the shank fitted. They also had two opposite projecting lips to fit into the groove, the idea being to hold the reamer firmly and keep it from twisting. It was found afterward that these lips were not needed, and they were discarded. The reamers were driven both by hand and by steam. In charging the holes two methods were used, as shown in Fig. 28. In one the powder was placed at the bottom of the drill hole, a wad of grass was then forced down to within 2 to 4 ft. of the powder, and then the tamping was put in. This left an air space or chamber above the explosive. In the other method the wad of grass was put in first, keeping it about 3 to 4 ft. above the bottom of the hole, then putting in the powder, and then the tamping. In this case the air space or chamber was below the explosive.

The factor determining which method of charging to use depends greatly on the tightness of the bed, that is to say, whether the seam separating the ledges is or is not well defined, or, in quarry parlance, whether or not the bed is free. Clay tamping was generally used, and sand tamping seldom. The series of holes was fired simultaneously by an electric battery.



GENERAL METHOD OF CHARGING HOLES IN QUARRY



METHOD OF CHARGING USED OCCASIONALLY.

FIG. 28.

The details of a shot made on the evening of October 1st, 1900, may be of interest. The ledge was about 250 ft. long and 18 ft. wide, the west half was about 10½ ft. thick, and the east half 8½ ft. thick. The drill holes were of the usual tapering diameter, 2½ in. wide at the top, and extended to within about 6 ins. of the bottom of the ledge. There were sixty-four charges, spaced about 3 ft. 10 ins. apart, and 150 lbs. of powder was used. The powder was placed in the bottom

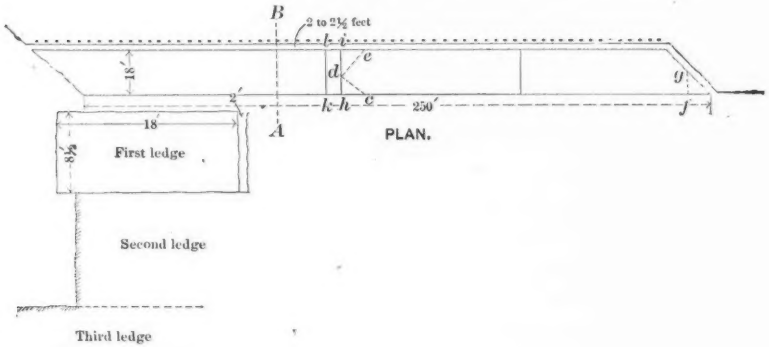
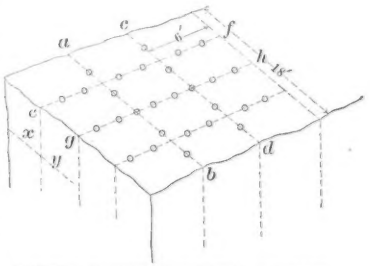


FIG. 29.

of each hole and then a wad of grass was put in, leaving an air space of about 3 ft. above; the remainder of each hole was tamped with clay.

The position of the ledge after the shot is shown in Fig. 29. The ledge was moved out bodily from 2 to 2½ ft. toward the quarry. Only a few cracks were made across the ledge. The weight of the stone moved was more than 3 500 tons.

Openings are made at the cracks, by first drilling along the lines *c–d*, *d–e*, *f–g*, and taking out angle stones and rubble until an opening is made. After the ledge is shot off it is cut into rectangular blocks, about 6 x 18 ft. (or 7 x 18 ft. for top angles), by drilling along the lines, *a–b*, *c–d*, etc. (see Fig. 30), 6 ft. apart, five holes being drilled in each line. Then each block is cut into four by drilling and blasting along the lines, *e–f*, *g–h*, etc. When necessary, each block is split by boring into the side, as at *x–y*, and splitting by wedges or light charges. In charging the holes along the lines, *a–b*, *c–d*, etc., about as much powder is used as can be held in the palms of two hands. The top ledge requires more powder than any of the others, as it is a softer limestone.



SKETCH SHOWING GENERAL METHOD OF CUTTING UP A LEDGE.

FIG. 30.

On October 24th, 1900, a block of stone 180 ft. long and 18 ft. wide with an average thickness of 9 ft., was blasted from the second ledge, at the eastern end of the north face of the quarry. A line of holes was drilled 18 ft. from the face of the top ledge, and about 3 ft. 6 ins. apart. The holes varied in diameter from 2½ to 1¾ ins., and they were from 8 to 9 ft. deep. There were fifty-two holes in the line, and three kegs, or 75 lbs. of powder were used, the holes being fired simultaneously by electricity. The holes were tamped with sand instead of clay. Sand gives very good results and saves a great deal of time in loading, as it does not require as much tamping. The fifty-two holes were loaded in an hour, while it would have taken at least 2½ to 3 hours to load with clay. In case the charge fails to explode, it is much easier to clean out holes which have been tamped with sand. To clean out a

charge, a hose is attached to a small pipe and steam is blown into the hole; water is also allowed to run in, and thus blow out the charge. The block described weighed about 2 400 tons, and was moved 2 ft.

The best capping stones came from the first three ledges on the north side of the quarry, and toward the eastern end. Very little capping stone was obtained from the bottom or fourth ledge, as it was very flinty and hard to work. For this reason it was used mostly for rubble. All courses on the north side at the west end were much laminated, and therefore, were used principally for rubble.

Referring to Fig. 31, which is a cross-section of the upper part of the superstructure of the stone breakwater, it will be observed that the extreme top is composed of three separate stones, which are

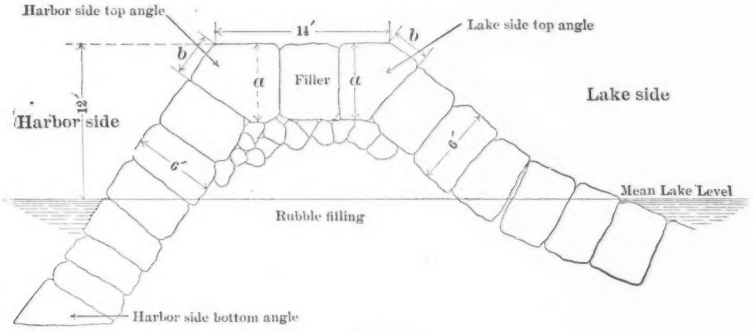


FIG. 31.

termed, respectively, the harbor-side top angle, the lake-side top angle and the filler. These angle stones, as well as the harbor-side bottom angles, were all quarried to the shape required by blasting, suitable templates being used to locate the drill holes.

Numerous fissures or cracks crossed the quarry face at an angle of about 45° and, in every instance, advantage was taken to utilize the cracks as one of the faces of the stone. In other cases the stones were quarried especially out of the whole. The depth of the stone, a, closely approximated 6 ft., while the dimension, b, varied from 1 to 3 ft.

About 2 200 stones of each kind, or 6 600 in all, were quarried. More than 40 000 stones of all kinds, for the revetment and capping, were used in the work.

As previously mentioned, Sargeant steam drills are used in the quarry. There are three sizes, large, medium and pony, designated as *F*, *C*, and A^{35}. Generally, six large, twenty-one medium and seven pony drills are in service.

The large drills are capable of drilling daily about 68 ft., the medium drills, 58 ft, and the pony drills, 22 ft. The latter were used mostly on the sides of large blocks which required splitting, or in facing up badly-shaped stones.

Steam for the drills is furnished by five horizontal fire-tube boilers of about 40 H.-P., and carrying 75 lbs. of steam. The boilers are about 18 ft. long and 4 ft. in diameter. The fire-box is about $4\frac{1}{2} \times 3\frac{1}{2} \times 3\frac{1}{2}$ ft. There are fifty-four 3-in. fire tubes, 11 to 12 ft. long. The heating surface is 546 sq. ft. The boilers were made by the Erie City Iron Works, of Erie, Pa., and by Farrar and Trefts, of Buffalo, N. Y. They are on the level ground about 100 ft. from the face of the quarry, the steam being carried to the drills in uncovered pipes, as the quarry is not worked during the winter.

There are sixteen derricks for handling the stone. They are of the ordinary mast and boom type, guyed by six lines of 1-in. galvanized-wire cable. The mast is 50 ft. high, with a 45-ft. boom, both of pine. The castings were made by the American Hoist and Derrick Company, of St. Paul, Minn. These derricks can handly safely a 20-ton block. The boom was usually kept in a fixed position, and was raised and lowered by hand.

There are eight hoisting engines, and, with one exception, they are of the usual skeleton type; that is, without boilers attached. There are seven double-drum engines with double cylinders, 8 x 12 ins., and are rated at 20 H.-P. All were made by M. Beatty and Sons, of Welland, Ontario. There is also one hoist, with boiler attachment, made by the American Hoist and Derrick Company, of St. Paul, Minn., having 7 x 10-in. cylinders. Each engine works two derricks, doing the hoisting only.

Steam for the skeleton engines is supplied by two boilers similar to those supplying the drills. A hoisting engine with boiler, and 8 x 12-in. cylinders is used for drawing the loaded cars up the inclined plane. From 8 to 12 loaded cars constitute a load.

Water for the boilers is taken from Lake Erie during warm weather, by a 6 x 4 x 6-in. Worthington pump at the loading dock,

and having a capacity of 75 galls. per minute. The water is pumped to an elevated tank at the quarry, through a 2-in. pipe laid beside the railroad.

In freezing weather the water from the lake is shut off and water is taken from the quarry pit, where it accumulates rapidly and is taken care of by two Worthington pumps: A 7½ x 7½ x 6-in., with a capacity of 300 galls. per minute; and a 7½ x 5 x 6-in., with a capacity of 100 galls. per minute. Steam for these pumps is furnished by a 25 H.-P. boiler made by Farrar and Trefts, of Buffalo, N. Y.

The loading plant at the dock consists of two large derricks, each operated by an 18-H.-P. double hoisting engine with 7 x 10-in. cylinders, with boiler attached. The derricks are swung by a 10-ft. hori zontal bull wheel.

The rolling stock consists of two small locomotives and about one hundred flat cars, also a number of dump cars.

The beds of the flat cars are 10 ft. long, 5 ft. wide and are 2 ft. 9 ins. above the rail level. The side sills are 6 x 10-in., the end sills 6 x 9-in., framed with their tops 5 ins. above the side sills, a 4 x 5-in. filler being placed on top of the latter to even up. All the woodwork is white oak.

The wheels are of cast iron, 2 ft. in diameter. The cars were made by the Union Car Company, of Depew, N. Y.

The skips or boxes for carrying rubble are of 2-in. white oak. They are 7 ft. long on top, 5 ft. on the bottom, 5 ft. wide and 2 ft. deep, and each carries from 3 to 4 tons of stone.

Organization of the Force.—A superintendent has general supervision of the entire quarry. Immediately under him there is a walk-in gboss whose main duty is the loading of the stone. Four foremen have charge of quarrying.the capping stone and laying out work for the drillers, each having his own section of the quarry. There is also one foreman for each of the sixteen derricks, who has from six to eight men under him. The stripping gang consists of a foreman, ten laborers, and the necessary teams. A gang of three men in charge of a foreman attend to the track repairs. The blacksmith force consists of ten smiths and nine helpers, the main work being the sharpening of the drills. In addition, there are machinists, carpenters and other artisans. The total force averages about two hundred and seventy men.

The wages paid at the quarry were as follows:

Superintendent	$100.00	per month.
General foreman	85.00	" "
Machinists	70.00	" "
Time keeper	60.00	" "
Teams	0.30	per hour.
Locomotive engine drivers and blacksmiths	0.25	" "
Foremen	0.22½	" "
Drillers (on steam drills)	0.20	" "
Hoist enginemen, firemen, blacksmith's helpers, carpenters and watchmen	0.17	" "
Driller's helpers and laborers	0.15	" "
Water boys	0.10	" "

TABLE No. 25.—Total Output of the Canadian Quarry, by Years; and Cost of Labor only, Per Ton of Stone Quarried.

Season.	Rubble, in tons.	Capping stone, in tons.	Total stone, in tons.	Amount paid for labor.	Cents per ton for labor.
1897	27 501.5	383.4	27 884.9	.....	.....
1898	97 269.7	16 078.7	113 348.4	.....	.....
1899	111 557.4	42 425.1	153 982.5	$72 008.80	47
1900	122 946.0	54 988.7	177 934.7	72 576.83	41
1901	167 795.1	77 531.7	245 326.8	81 987.74	33
1902	137 279.2	93 470.9	230 750.1	83 519.37	36
Total	664 348.9	284 878.5	949 227.4	.....	.....

During the season of 1902 the following explosives were used:

Dynamite,	5 450 lbs., at 12 cents	.....	$654.00
Powder,	41 348 " " 5 "	.....	2 067.40
Fuses,	68 700 " 5 "	.....	3 435.00
			$6 156.40

The cost of explosives was about 2¾ cents per ton of stone quarried, 1 lb. of dynamite being used for every 42 tons of stone quarried, and 1 lb. of powder for every 5 tons of stone.

The coal consumption per day was as follows:

Boilers for drills,	5 at 1½ tons.....	7½ tons.
Boilers for derricks,	2 " 1½ "	3 "
Boiler for pumps,	1 " 1½ "	1½ "
Hoisting engine,	1 " ½ "	½ "
Hoisting engine,	2 " 1½ "	3 "
Locomotives,	2 " 1 "	2 "
Incline engine,	1 " 1½ "	1½ "
Total.....		19 "

TABLE No. 26.—Analysis of Limestone from Quarry at Windmill Point, Ontario, used in Buffalo Breakwater.

Sample.	Moisture.	Silica.	Iron and alumina.	Calcium carbonate.	Magnesia.	Phosphoric acid.	Remarks.
No. 1.....	0.226	30.15	1.03	66.84	1.29	0.021	Top ledge.
2.....	0.29	30.34	1.27	65.05	1.30	0.025	Middle "
3.....	0.36	45.30	0.94	50.29	0.86	0.16	Bottom "
1c.....	0.20	21.33	0.99	72.52	1.39	0.009	Intermediate "

Conclusion.

Since the preparation of this paper, the breakwater extension to Stony Point has been completed, as far as the contract with Hughes Brothers and Bangs is concerned. The last stone in the rubble-mound or stone breakwater was laid, with simple ceremony, on September 24th, 1903.

The entire work done during the season of 1903 was the reconstruction of the sunken part, in strict conformity with the stipulations, as outlined in another part of this paper.

Such capping stone as were readily recovered by means of a diver were taken out and reset. The number recovered was about 1 800, or about 11 000 tons.

For the greater part of the season there were three floating derricks on the repair work, one generally resetting the recovered capping stone, and one setting the new capping stone. The other derrick was engaged part of the time in handling the rubble hearting, and the

remainder of the time in placing rip-rap in front of the adjoining South Harbor Section. The cost of the reconstruction was as follows:

27 634.3 tons of rubble from Canada, at $0.80....	$22 107.44
15 338.2 " capping " " 1.25....	19 172.75
Force account, recovering and resetting capping stone.....	15 583.04
	$56 863.23
Cost to December 15th, 1902.....	908 139.76
Total.....	$965 002.99

The total cost of the work was $1 727 000.84, exclusive of office, inspection and other expenses.

The details of the various sections are shown in Table No. 27.

It is a matter of interest to note that the final cost is less than the original estimate, by which the bids were canvassed, which amount was $1 765 450.63.

TABLE No. 27.—Total Cost of Extension to Stony Point, Buffalo Breakwater Construction.

Hughes Brothers and Bangs, Contractors.

Contract dated January 27th, 28th, 1897.

Sand-Catch Pier:						
Piles	462		at	$11.00	$4 422.00	
Waling	1 139.35	lin. ft.,	"	0.25	284.88	
Tie-rods, screw bolts and straps	14 700.9	lbs.,	"	0.02½	367.52	
Stone filling	1 469.9	cu. yds.,	"	1.06	1 558.09	
						$6 632.44
Stone Breakwater:						
Gravel	245 242	cu. yds.,	at	$0.13	$31 881.46	
Rubble, U. S.	203 391.4	tons,		.....	162 702.60	
" Canada	492 042.1	"		.....	386 687.47	
Capping stone, Canada	300 216.7	"		.....	368 148.43	
Force account work					15 583.03	
						965 002.99
South Harbor Section:						
Trench excavation	357 461	cu. yds.,	at	$0.18	$64 342.98	
" filling	321 695	"	"	0.13	41 820.35	
Foundation stone	157 031.4	tons,	"	.....	117 654.49	
Timber cribwork	2 763	lin. ft.,	"	92.37	255 218.31	
Mooring cleats, extra timber, etc					2 723.62	
						481 759.75
Stony Point Section:						
Trench excavation	206 861	cu. yds.,	at	$0.18	$37 234.98	
" filling	193 383	"	"	0.13	25 139.79	
Foundation stone	19 170.8	tons			12 995.78	
Timber cribwork	2 826.9	lin. ft			197 065.15	
Mooring cleats, extra timber, etc					1 169.96	
						273 605.66
Total cost						$1 727 000.84

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE FATIGUE OF CEMENT PRODUCTS.

Discussion.*

By Messrs. E. R. Buckley, L. F. Bellinger, A. L. Johnson and H. F. Dunham.

E. R. Buckley, Esq.† (by letter).—The experiments to determine the fatigue of cement products, which are being carried on in the testing laboratory of Washington University, under the direction of Professor J. L. Van Ornum, are extremely interesting and practical. Professor Van Ornum has started a line of investigation which has heretofore been practically overlooked. It is hoped that he may be able to procure data showing some uniformity in the rate of weakening of cement products under repeated loading. It is thought, however, that a series of experiments showing the rate of weakening under a constant load below the ultimate strength would perhaps be of even greater commercial importance than the experiments now being conducted. Mr. Buckley.

In 1898, the writer recognized the same phenomenon of fatigue in stone, while making a series of tests, in the preparation of a report on the "Building and Ornamental Stones of Wisconsin." On pages 367 and 368 of that report, will be found the following observations:

"No data are thus far available from which one can glean any knowledge of the effect of long continued pressure below the point of rupture on the strength of the rock. Neither have data been obtained indicating the effect of intermittent stresses (repeated loading) on the rupturing of rocks. In making the compressive strength tests

* This discussion of the paper by J. L. Van Ornum, M. Am. Soc. C. E., printed in *Proceedings* for August, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to December 25th, 1903, will be published subsequently.

† Director, Missouri Bureau of Geology and Mines.

Mr. Buckley. in the preparation of this report, a number of samples were placed in the 100 000-lb. Riehlé testing machine, which could not be crushed. These samples were removed, and afterwards crushed in a 300 000-lb. machine, with the results indicated in the accompanying table. The apparent loss in strength in some of the samples cannot be entirely attributed to the intermittent character of the pressure. It is probably due, to some extent, to the fact that the samples were chipped at the corners and edges when in the first machine. These and other causes incident upon a change of machines may partially account for the losses, but, nevertheless, the results would seem to indicate that an actual decrease in strength is occasioned by continued or intermittent pressure below the ultimate strength. Further experiments along this line are needed."

The following is the table referred to in the paragraph quoted:

"TABLE SHOWING THE DIFFERENCE IN CRUSHING STRENGTH THROUGH INTERRUPTED PRESSURE."

Name of Quarry.	Crushing Strength.	
	100 000-lb. Machine.	300 000-lb. Machine.
Pike River Granite Co.	25 000	27 887
New Hill O'Fair (Granite)	25 000	27 262
Milwaukee Monument Co. (Granite)	25 000	38 063
Lenthold Quarry (Granite)	25 000	20 875
Washington Stone Co. (Limestone)	27 855	29 526
Gillen Stone Co. (Limestone)	25 000	20 308
Gillen Stone Co. (Limestone)	24 783	14 869

Four of these tests gave an increased resistance in the larger machine, while three of them exhibit a decrease of several thousand pounds per square inch.

In connection with the preparation of a report on the building stones of Missouri, the writer contemplates verifying, if possible, the conclusions reached in his Wisconsin report relative to the fatigue of stone.

It is believed that these experiments will be fruitful of results which will have a commercial, as well as a scientific, value.

Mr. Bellinger. L. F. BELLINGER, M. Am. Soc. C. E. (by letter).—This paper, with its interesting diagram, will be certain to attract considerable attention from designers in concrete. As it is the first attempt to place on a scientific basis certain phenomena which have no doubt been noticed by all engineers performing laboratory tests and full-size tests of the materials mentioned.

The nomenclature of the paper includes "progressive failure" and "gradual fracture" under the heading of "fatigue." The latter seems to be a good term for neat-cement tests which fail by tensile

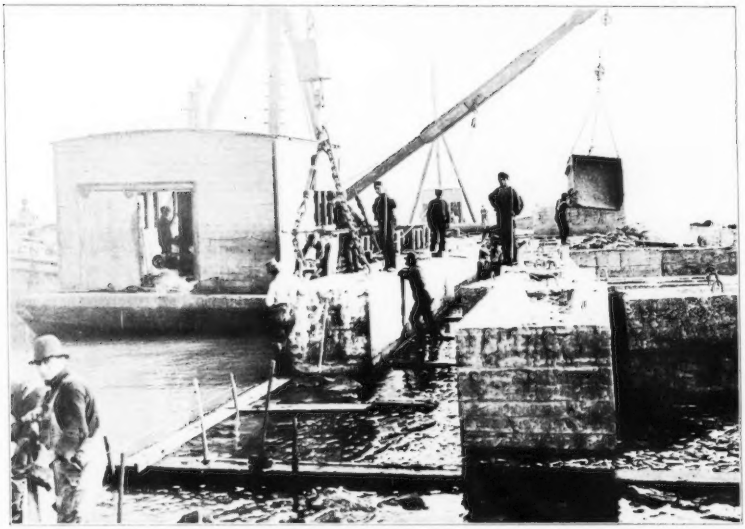


FIG. 1.—SOUTH HARBOR SECTION. SETTING CONCRETE BLOCKS ON HARBOR SIDE. 1901.



FIG. 2.—SOUTH HARBOR SECTION. CONCRETE SUPERSTRUCTURE. PARAPET WALLS IN PLACE. 1901

stress, below the ordinarily determined ultimate strength, after a short time. The writer has in mind some 7-day tests of neat Portland cement briquettes which were tested in a Riehlé machine having a capacity of only 1 000 lbs. The briquettes were left with the stress of 1 000 lbs. per square inch on them until they broke. The length of time varied considerably, from zero to one minute, and one briquette carried that load for 1½ minutes before failure occurred. This type of failure might be called "fatigue" in the strictest sense. So also might be called the failure of full-size floor slabs of reinforced concrete construction. Seven of these floor slabs were tested under the writer's supervision, with the following general results: Each test floor consisted of three bays, of 6 ft. span and 5 ft. width, the center bay only carrying the test load of pig iron, concentrated along its center line. The reinforcement of the concrete was Clinton wire-cloth, or expanded metal of various sizes. In general, it was noted that the load which caused the first noticeable deflection, $\frac{1}{32}$ to $\frac{1}{16}$ in., was just about one-half of the load which caused the failure of the concrete; that is, the cracking of the concrete at the haunches or the middle of the span, exposing the metal. It was noted that the workmen could keep piling up the pig iron after the actual failure until the load was 20% more, before the load fell through the floor, rupturing the steel. A further important note was, that the load at actual failure, as noted above, if left alone, caused the spalling off on the bottom of the slab to continue more or less rapidly, indicating the destruction of the floor in time, through "fatigue" of the materials. Mr. Bellinger.

When it comes to compression tests, there is another and older term than "fatigue" describing the action of material under test quite fully, and that is "disintegration." It is difficult to get a good uniform bearing for crushing brittle material. If the plates at the jaws of the testing machine are hard, some high point of the specimen is crushed or split off before the remainder receives its share of the load; if the plates are soft, the material flows into the pores of the test piece, and, acting like a wedge, pushes off a few grains at a time, or destroys the cohesion between the grains, a little at a time, until the specimen fails. Examples of repetition of small applications of stress are: The use of stone hammers to split rock; the wearing away of rocks by rolling in the beds of streams, and by the action of river currents; the disintegration of concrete sea-walls, between low water and high water, by wave and ice action, and, when the coarser particles are reached, by the freezing of water between these particles.

The analogy between the "fatigue" of cement in compression and the "disintegration" of concrete, stone, etc., in the examples cited is plain. In each case it is a question of the number of applications of stress, by machine, freezing, impact of ice cakes, etc., and the amount of this stress at each application. This question is the one

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Timber Cribwork.—The timber-crib breakwater, which is part of the project of the extension to Stony Point, adjoins the stone breakwater on the south, being a prolongation of the latter, with the exception that, owing to the different cross-sections of the two structures, the axes are not coincident, although parallel.

The breakwater is 2 739 ft. long, measured along the lake face. It consists of sixteen cribs, one of which is 60 ft. long, 36 ft. wide and 22 ft. deep, and is placed at right angles to the axis of the breakwater, projecting 24 ft. beyond the general harbor face of the work, thus forming an L, to be used as an emplacement for a lighthouse, protecting the South Harbor entrance.

The remaining fifteen cribs are each 180 ft. long, 36 ft. wide and 22 ft. deep, differing in this respect from the Stony Point breakwater, where the cribs are each 60 ft. long, with the exception of one shallow crib, 120 ft. long.

The 180-ft. cribs are composed of three grillage bottoms, each 60 ft. long, 36 ft. wide and 4 ft. high. These bottoms are bolted together firmly at each of the two joints, by seven 1¼-in. screw-bolts, 26½ ins. long, making a composite grillage bottom 180 ft. in length. The remaining eighteen courses are then laid up in the usual manner, great care being taken to break joints properly. The arrangement of the cross- and longitudinal- ties, and vertical posts, was identical with that of the 60-ft. cribs. There was no difficulty in sinking these long cribs; in fact, they were placed and sunk more readily than the shorter ones, and an almost absolute alignment was obtained. A decided advantage over the shorter cribs is the obliteration of two joints, which is quite a consideration.

Subsequent experience, however, demonstrated that these cribs should have been built with at least two solid transverse bulkheads, or, better still, with five, one for every 30 ft. Such bulkheads would have resisted the tendency of the long cribs to "warp" at the top, due to the buffeting of heavy storms.

The first of these 180-ft. cribs, designated as Nos. 48–49–50, was begun early in November, 1898. At the close of the season, December 9th, 1898, this crib had been built nine courses high.

Work was resumed on May 4th, 1899, and the crib was sunk in position on August 14th, 1899, forming the first 180-ft. crib of the substructure of the South Harbor Section. Crib No. 47, known as the L-crib, was sunk on July 20th, 1899.

The 180-ft. cribs contain the following quantities:

Hemlock	233 328	ft., B. M.
Pine	41 304	" "
Total	274 632	" "

Screw-bolts	171	1¼ x 37 ins.	at 19.51 lbs.	3 336.21	lbs.
"	472	1¼ x 26½ "	" 15.85 "	7 481.20	"
"	44	1¼ x 25 "	" 15.33 "	674.52	"
"	8	1¼ x 19 "	" 13.25 "	106.00	"
Drift-bolts	1 620	1⅛ x 32 "	" 9.01 "	14 596.20	"
"	1 856	1⅛ x 24 "	" 6.76 "	12 546.56	"
"	462	½ x 12 "	" 0.85 "	392.70	"
Total				39 133.39	"

The weight of the screw-bolts includes one nut and two washers with each bolt. The washers are 5 ins. in diameter and ½ in. thick.

The season of 1899 was one of great activity. Nine 180-ft. cribs were built and sunk and the superstructure completed over them. In addition, five 180-ft. cribs were built nineteen courses high, which included all the hemlock timber; another was built six courses high. At the close of the season 1 682.2 ft. of timber-crib breakwater had been completed.

Tifft Farm Framing Yard.—During the summer of 1898 the contractors installed two machines to lessen the labor of framing, a gaining machine and a tie-head machine, both manufactured by the Lake Shore Iron Works, of Marquette, Mich., for the Holley Manufacturing Company. They were housed in a building called the mill.

The mill was a wooden building, near the middle of the framing yard, just off the construction dock, 36 ft. wide and 60 ft. long. The boiler-house, 14 x 28½ ft., was at one end of the mill. The building also contained a butt-off machine, operating a 30-in. circular saw. The engine-room, 13½ x 15½ ft., was in one corner of the mill, and contained a Westinghouse engine. Adjoining the engine-room was a room, 12 ft. long, containing a Westinghouse air compressor. The air tank was outside of the mill.

Adjoining the air-compressor room there was an 8 x 12-ft. tool-room. In the central part of the mill were rollways on which the

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INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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SOUTH AFRICAN IRRIGATION.

Discussion.*

By L. J. Le Conte, M. Am. Soc. C. E.

Mr. Le Conte.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The attempts at irrigation described by the author are certainly very crude, for a thriving British Colony, and lead one to suppose that for this some climatic condition is responsible.

The first thing noticed is the extraordinary variation in the annual rainfall, namely, from 6 to 33 ins. In this respect, Cape Colony is somewhat like certain sections of California, and for sundry reasons it may be assumed that mammoth catchment reservoirs will become necessary, in the natural course of events, in order to tide over the lack of water during dry years, which seem to come in series. This fact alone, more than any others, adds enormously to the first cost of the proper development of an irrigation system.

It is unfortunate that so few run-off records are in existence, for they are the most reliable data upon which the engineer can depend. He should exercise unusual conservatism in selecting the minimum rainfall, and in assuming the percentage of probable catch, if he wants to get a reliable supply.

Table No. 10 contains the results of more than thirty years' actual experience in California, with storage reservoirs, and will be helpful in guiding the judgment.

From this table it will be readily seen that enormous storage room is absolutely necessary in order to insure a reliable supply of 1 000 000 galls. per day.

* Continued from October, 1903, *Proceedings*. See August, 1903, *Proceedings*, for paper on this subject by Francis Robert Johnson, M. Am. Soc. C. E.

TABLE No. 10.

Mr. Le Conte.

Average minimum annual rainfall, taking the three driest years in succession.	Number of square miles of watershed required to furnish daily 1 000 000 galls. during a severe drought.	Maximum storage room advisable for each square mile of tributary watershed, in millions of gallons.	Maximum storage room advisable for each million gallons per diem actually delivered, in millions of gallons.
San Francisco.			
No. 1: 40 ins.....	3.00	280	849
No. 2: 35 "	5.00	250	1 250
No. 3: 30 "	7.00	200	1 400
No. 4: 29 "	6.25	225	1 406
Oakland: 17 "	9.00	150	1 350

The estimated minimum run-off, of 5% of the average rainfall, in South Africa, speaks for itself, and illustrates the severe droughts to which the country is subject at times.

The author's remarks about the Roman Dutch Law, which prevails in the Colonies, are quite amusing. His statement that:

"If there is one thing which the Roman Dutch Law recognizes, it is that actual beneficent use must be proved before any right to water can be obtained."

Such a praiseworthy law as this would be a God-send to California, and would do away with 90% of the litigation now going on, and which has brought forth decisions, first one way and then another, until the whole legal system is racked with doubts and uncertainties on every point.

The Common Law of England is in force in California, and this law will never fit the vital necessities of the community, and will have to be modified, sooner or later, to meet the demands of common sense.

It would seem, however, that, after all, the Colonial Government is naturally the proper party to undertake the construction of suitable irrigation works.

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SOME RAILWAY CONSTRUCTION IN OKLAHOMA.
Discussion.*

By Messrs. EMILE LOW and H. F. DUNHAM.

Mr. Low. EMILE LOW, M. Am. Soc. C. E. (by letter).—It is to be hoped that this paper will elicit full discussion, especially as so many railroad engineers are enrolled in the Society. Some years ago a somewhat similar paper was presented, and the writer was the only one who took part in the discussion. It is difficult to explain why so few members contribute to the discussions. It may be from lack of interest, or perhaps railroad engineers think they are too busy.

If a map of the line accompanied the paper it would be very advantageous, as the alignment and profile of a railway line are always an interesting study, particularly to the locating or constructing engineer. The character and magnitude of the grading are grasped more readily when thus graphically presented.

Mr. Allan gives quite a number of illustrations and plans of arch- and box-culverts, but it is to be regretted that he has not stated the manner or method by which the sizes of the various openings were determined.

As most engineers are aware, the determination of culvert openings is far from scientific. It would not be far from the truth to say that in most cases they are determined by guesswork, and that much depends on the judgment of the guesser.

One bad feature of the culverts, as built, is the offset at the junction of the wing-walls and the barrel, the tendency of which is to

* Continued from October, 1903, *Proceedings*. See August, 1903, *Proceedings*, for paper on this subject by A. G. Allan, Assoc. M. Am. Soc. C. E.

Mr. Low.

TYPICAL SECTION OF 16-FOOT ARCH-CULVERT.

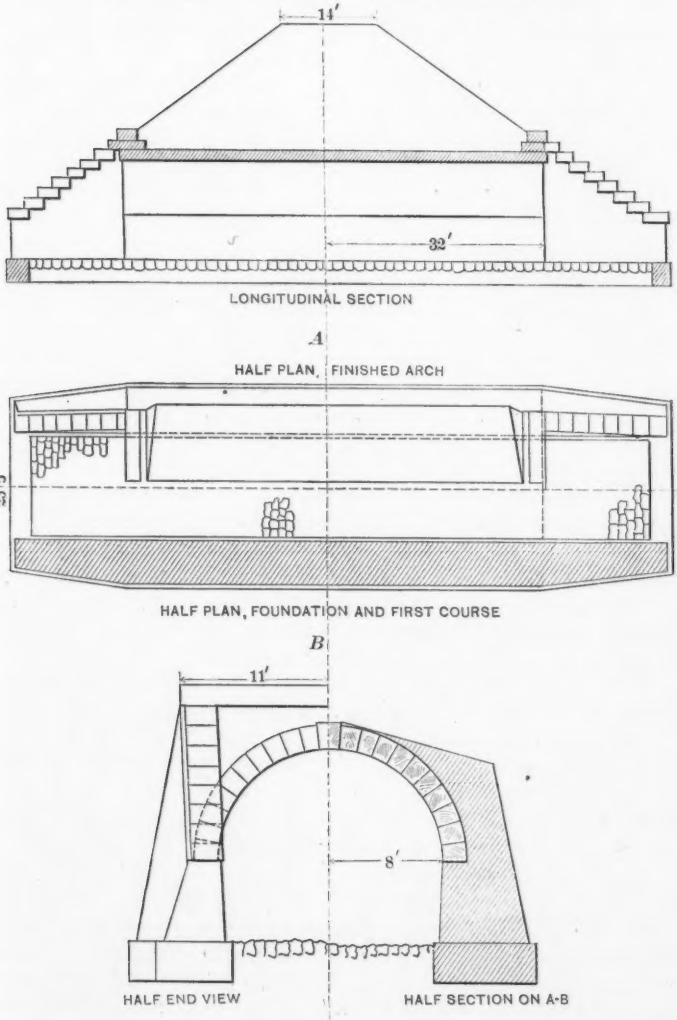


FIG. 11.

Mr. Low. contract the waterway. It is also a place for the lodgment of drift-wood. Also, would it not have been better to build a single arch, of a somewhat smaller waterway, than the double one?

One good feature is the furnishing of the cement by the railroad company. This is the practice of a number of first-class railroads, and has much to commend it.

Fig. 11 is a typical plan of an arch-culvert, indicative of the practice of a number of prominent eastern railroads, and is the type which the writer prefers.

This plan shows parallel wing-walls, but flaring walls are often to be preferred. In every case, however, the offset at the junction of the walls and the barrel is avoided.

Mr. Dunham. H. F. DUNHAM, M. Am. Soc. C. E. (by letter).—It would be interesting to trace by the aid of sketches and photographs the gradual change from difficult to simple designs for wing-walls for arch bridges. Every engineer familiar with early railway construction in this country has felt a thrill of genuine pleasure as well as astonishment when standing upon the parapet of a high masonry bridge above the amphitheater formed by wing-walls that follow for 90° the circumferences of circles having for their radii the "distance out" and for their centers points in the lines of the bench-walls extended. The effect is intensified if the broad area is well covered by large forest trees. But when it is necessary to widen the roadbed and increase the number of tracks—that invites a different state of mind.

The wing-walls should be built in the line of the culvert walls, and begin to batter, if they are battered at all, at the skewback or springing line of the arch. There may be instances in cities and conspicuous places where, for appearance, the design shown by the author is warranted, but, generally speaking, and especially in the West, where it may not be quite certain whether a new road will pay 11% or only 10% upon the investment, any change that makes the work less expensive and stronger while adding to the safety should invite attention.

Offsets and corners in masonry are sources of annoyance and expense that the contractor usually "figures in." Offsets at the end of a culvert invite accumulations of drift; so do wedge- or funnel-shaped passages, while the straight-wall wings offer at their ends the same width of passageway that the culvert offers, and if flood-wood, fence rails, or what not, stop there, causing the water to dam up and overflow, the overflow goes through the culvert and will continue to do so after such dam has reached a height above the top of the culvert opening; so that the straight-wing, instead of embracing trouble, is a rude fender to keep trouble away. Especially is this true of a small opening under a high embankment.



CULVERT ON THE LINE OF THE WHEELING BRIDGE AND TERMINAL COMPANY.

Mapu

The parapet and coping are diminished by such construction. Extension of the culvert becomes an easy matter, and, as for appearance—there is a possibility of getting used to it. Mr. Dunham.

To illustrate further these advantages, Plate LXVII is introduced, and shows a culvert, built in 1890, on the line of the Wheeling Bridge and Terminal Company, now owned by the Pennsylvania Railway. The Chief Engineer was the late Job Abbott, M. Am. Soc. C. E., and the writer was Engineer in Charge.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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FILTRATION FOR PUBLIC WATER SUPPLIES, WITH ESPECIAL REFERENCE TO THE DOUBLE FILTRATION PLANT AT BREMEN, GERMANY.

Discussion.*

By Messrs. W. Kiersted, Howard W. Underwood, W. B. Fuller, George A. Soper and T. H. Wiggin.

Mr. Kiersted.

W. Kiersted, M. Am. Soc. C. E. (by letter).—The writer has read this paper with much interest, particularly as it records the methods of operating sand filters abroad and indicates the character of supervision needed to insure successful results in filtering public water supplies. The description is confined to the slow sand or biological filter, the merits of which has been long and successfully established.

It is generally recognized that the successful operation of any kind of water-purification plant requires skilled supervision, but it is important that the mechanical control of the filter should be so complete and the necessary examination of the water so standardized that the amount of skilled supervision can be safely reduced to a minimum, in the interest of economy of operation.

Long experience with biological filters abroad has doubtless developed structural standards, a permissible range of filter velocity, and approved methods of filter manipulation, which, when duly regarded, insure exposure of the water to the biological processes in a

* This discussion (of the paper by Eugen Goetze, Esq., printed in *Proceedings* for September, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to December 25th, 1903, will be published subsequently.

ripe filter long enough to become practically purified and perfectly wholesome, provided the raw water as introduced into the filter is not too turbid. Thus far, efforts seem to have been directed toward the perfection of standards governing the purity and wholesomeness of the output of the filter. Such standards are absolutely essential, of course, and, when once established, they must control, within practical limitations. In order to conform to them in practice, it becomes necessary to vary somewhat the manipulation of the filter, according to the character of the raw water introduced—the more turbid the raw water is, the slower must be the velocity of filtration in order to meet the requirements of the controlling standard of purity. But, as the author has well stated, "the possibility of reducing velocity in practice soon reaches an end," and he proposes double filtration as a means of securing a filtrate of the desired purity without a prejudicial change of filtration velocity, whenever the turbidity and bacterial contents of the water exceed that which admits of conformity to the standard of purity after single filtration. Mr. Kierstead.

Doubtless double filtration, as practiced in Bremen, fills the requirements of the situation admirably, as it is necessary for only a brief period of each year. But, if the usual condition of the river water were one of a high degree of turbidity, the writer believes the investment in filters of sufficient capacity for double filtration regularly practiced would prove greater than an investment in a combination of settling basins and single-filtration filters accomplishing equally good results.

Many rivers in the United States furnish water of so great a degree of turbidity for the greater portion of each year that thorough preparation of the water in advance of filtration is required.

Thus far, sedimentation in settling basins has proved the best method for preparing the water for filtration. However, with many waters, chemical treatment in the settling basin is imperative in the proper reduction of turbidity, and by its assistance it is believed the turbidity may be so reduced that single filtration will afford a perfectly wholesome water after the filter is in proper condition for biological work.

The writer believes that a standard should be adopted for the turbidity of a water admitted to a biological filter, as in this way alone can a uniformity of filtering velocity and of manipulation be secured which enables a filter to deliver uniformly an acceptable product. He would make filtration altogether a refining process, and would meet the fluctuation of turbidity of the raw river water in the settling basins and there modify the manipulation and treatment of the raw water to suit its changeable physical characteristics.

Incidentally, there will be a reduction of bacteria during the partial clarification process in the settling basin, but the writer

Mr. Kiersted. would fix no standard for bacteria reduction during this process, as this is obviously the work which the biological filter is expected to perform.

The adoption of such a standard for the raw water would result, among other things, in minimizing the amount of skilled attention required in the operation of the water purification plant, because the conditions surrounding the operation of the filters would be more nearly uniform, day after day, and the variation of the physical characteristics of the water would be readily observable in an open settling basin and controlled accordingly. Moreover, it is believed to be cheaper to remove the accumulation of sediment from a settling basin than from a filter.

It is admitted, however, that some skilled attention is required to operate a settling basin successfully, particularly where circumstances require the use of a coagulant. But, in this regard, methods can be so thoroughly standardized that the skilled supervision can be made a comparatively easy matter.

Mr. Underwood. HOWARD W. UNDERWOOD, Jun. Am. Soc. C. E.—In his description of the Bremen filters, Mr. Goetze has called attention to many interesting points connected with their operation. One, which is especially interesting, as it is a method differing from that used in America, is the transportation and washing of sand, and it will, perhaps, be of interest to describe the methods used at the Philadelphia filters, and trace the progress made there.

Two systems, known as the Upper and Lower Roxborough filters, have been completed and in operation for some time at Philadelphia. At the Lower Roxborough filters, for some time after they were started, the dirty sand was removed from the beds in wheel-barrows and washed at a convenient time. In March, 1903, pressure and discharge pipes were placed in the filters, and since then the dirty sand has been transported from the bed directly to the washers by a portable ejector under water pressure. After passing through the washers, the sand is transported by water to the clean-sand pile.

The ejector is simply a hopper in which a horizontal jet of water passes through a sprayer pipe and flushes the sand down toward the nozzle. Ordinary heavy fire-hose is used to connect the ejector with the permanent iron pipes, which extend through the center of the filter. The dirty sand is not only removed from the bed by the ejector, but is also washed and delivered to the clean-sand pile, without extra labor. The force required, therefore, is only large enough to keep the filters scraped, as the men work at this all the time.

No additional water is required, as the ejector does the greater part of the washing, and not all the hoppers in the washer are required, as compared with washing directly from the pile.

At Lower Roxborough, with one ejector and a pressure of from 55

to 60 lbs., from 4 to 7 cu. yds. of sand per hour are removed and washed by four men, using from 2 800 to 3 000 galls. of water per cubic yard; or, in other words, from 14 to 15 volumes of water to 1 volume of sand. Mr. Underwood.

At Upper Roxborough, with two ejectors and a pressure of from 80 to 90 lbs., from 14 to 18 cu. yds. of sand per hour are removed and washed by seven men, using from 2 200 to 2 400 galls. of water per cubic yard, or from 11 to 12 volumes of water to 1 volume of sand.

The total cost of scraping the filters, removing and washing the sand, including all changes in the pipe, and the cost of water, varies from 40 to 60 cents per cubic yard.

The total filtering area at Lower and Upper Roxborough is 8.25 acres, and eight men are constantly engaged in scraping, removing and washing the dirty sand, which amounts to about 1 000 cu. yds. per month.

This demonstrates the effectiveness of the ejectors for cleaning a filter quickly, and also shows a great reduction in cost, as compared with removal by wheel-barrows and washing later.

As to the relative cleanness of the sand: Before the ejector was installed five hoppers were used, and the turbidity of the average scrapings, about 40 000 to 50 000 parts per million, was reduced to about 2 000 parts per million. At Upper Roxborough, at present, the ejector and one hopper are used, and the turbidity of from 40 000 to 50 000 parts per million is reduced to about 500 parts per million. As the sand is delivered from the ejector pipe, it has a turbidity of from 1 200 to 1 500 parts per million, and with proper means of removing the dirty water, it is believed that the ejector will give sufficient washing.

The average length of run on the Roxborough filters is about 35 days, and a rate of about 3 000 000 galls. per acre per day is maintained. From $1\frac{1}{4}$ to $1\frac{1}{2}$ ins. of sand are removed at each scraping.

William B. Fuller, M. Am. Soc. C. E.—The speaker has been very much interested in the description of the working of the Bremen filters, and especially in the ingenious method used to secure the benefits of double filtration of the water coming from filters when first put in commission. Mr. Fuller.

The principle of refiltering the first part of the run of a newly scraped filter, where it would be uneconomical to allow this filtrate to run to waste, is certainly in line with the best practice of filter operation, but the speaker would hesitate to recommend the accomplishing of this object in the manner described by the author.

One of the first tenets in the design of slow sand filters in America has been to make them as near fool-proof as possible, and to take especial care that there are no channels through which, either by accident

Mr. Fuller. or design, raw water can be run to the filtered-water conduits without passing through a sand layer.

It is feared that the existence of a by-pass may prove too great a temptation to a foreman desirous of making a record for long runs between scrapings, and the resulting economy of maintenance, and it is customary on this account to provide only one by-pass between raw and filtered water for use in case of accident, this by-pass being strongly guarded with locks and seals so that it cannot be opened without the knowledge of those highest in authority.

In the design shown, the seal of the syphon may be accidentally or designedly maintained after changing to single filtration, and in this manner raw water could be delivered directly into the filtered-water conduit.

The additional first cost of construction is also a bar to the adoption of the method described, as it may, and often does happen, that periods of greatest turbidity are coincident with periods of greatest consumption.

In America no definite rule has been laid down for guidance in the operation of filters, but it is customary to assume a sufficient purification if the average of the effluent from all filters gives a bacterial content of less than 100 per cubic centimeter.

If the principle is recognized, however, that the filtrate from each filter shall have less than the above bacterial content before entering the filtered-water conduit there will be no additional first cost in the double filtration proposed, as in any case provision would have to be made in the design for additional filters to take the place of those in the process of ripening.

In a design with which the speaker is now connected the principle has been recognized that it is the best practice not to turn the first filtrate from a newly scraped filter into the filtered-water conduit, and provision is made for the wasting of this water to an effluent-drain reservoir from which reservoir all water required for transporting and washing sand is to be pumped. This water can also be pumped back into the raw-water conduit if the sand washing and transportation does not require its use, and this cost of pumping, which is very small, owing to the small lift, is believed to be a good investment as an insurance against the improper use of by-passes.

Should the water from single filtration show turbid in the effluent, the remedy recommended by the speaker would be a preliminary filtration through a mechanical filter run at a high rate and without coagulant.

The author appears to be a great champion of automatic regulation, having automatic regulators on both the raw-water inlet and on the filtered-water outlet. This may be, and probably is the best method for small plants receiving raw water under pressure, but the speaker is opposed to their use where they can be avoided.

Mr. Fuller.

The taking of the raw water from a large reservoir of constant level, and the control of the effluents from a large number of filters from a central house by hand regulation appears to him to present a more nearly fool-proof combination than automatic regulation.

The author is wrongly informed as to the volume of water required for washing sand by the injector system, as the poorest ejectors in use at any of the plants known to the speaker do not require more than 15 volumes of water to 1 of sand, and the newest types compare favorably with the volumes required by the washer described by the author, with the additional advantages of transporting the washed sand to any distance.

Mr. Soper.

GEORGE A. SOPER, Assoc. M. Am. Soc. C. E.—This paper describes in a clear and instructive manner how its author has solved one of the most common and unsatisfactory problems of water purification. It is easy to filter the water of the Weser, at Bremen, under ordinary circumstances, but, at times, it may become very difficult. In fact, it is impossible to remove the impurities by a single filtration, and it becomes necessary to pass the water a second time through the filter bed.

In the purification of river waters, it may be said that such conditions are the rule in many of the Central and Eastern States. The frequency with which the periods of difficulty are met, and their duration and severity, are the important influences in deciding the means for assisting the filters. If exceptionally roily water is to be encountered only three or four times a year, as at Bremen, such an arrangement as that described by the author may offer the best solution. If the water is more often turbid, and the impurities to be removed are excessive in amount, it may be desirable to use large settling basins, as are common in America, or the suspended particles may be precipitated with chemicals, as in the United States and in some places in Holland. If the streams are comparatively short and the intervals of turbidity brief, the plant may be shut down entirely until the worst of the impure water has disappeared, as is practiced in England. Finally, if the effluent of a filter is objectionable only because of its bacterial contents, the water may be sterilized, for example, with ozone, as has been done successfully in Germany.

In determining in a precise way the factors upon which a choice of the most suitable means of preparing a water for filtration depends, and in treating it after filtration, lies an important field for further investigation.

To many it will be a new idea that a water may need any other treatment than filtration, for there is a general impression, outside of the engineering profession and among some persons in it, that if a water has been once filtered it must of necessity be pure. In frankly acknowledging the limitations of the filter at Bremen, and in affording

Mr. Soper. means for understanding wherein these limitations lie, the author has performed a useful service.

Those who have had occasion to design or operate a filtration plant, with a water which is usually clear but sometimes turbid, know the fallacy of supposing a filter to be capable of heavy work. To those who have a practical knowledge of water purification, it is evident that the capacity of filters of all kinds to handle suspended matters is limited, and that the conditions under which they can be operated safely must be known thoroughly and kept in mind constantly if results are required which are to be satisfactory analytically.

In relation to this it may be interesting to recall the definition of a filter given by the pioneer of water purification in America, the late James P. Kirkwood, M. Am. Soc. C. E. He called them "screens of the greatest delicacy." To-day Mr. Kirkwood's definition is illustrative rather than accurately descriptive. Filters are more than screens, yet they are like delicate screens in being able to remove fine particles of suspended matter and at the same time unable to handle a great deal of it.

Nothing in these remarks should be taken to indicate that the writer is opposed to the use of filters in the purification of water supplies. Engineers are forced to recognize the efficacy of filters in many ways and are not disposed to underrate their value. They have accomplished inestimable good in protecting communities of all sizes, from small villages to cities of the first class, against cholera, typhoid fever, and other infectious diseases. But it is not correct to assume that the whole art of water purification rests in the filters. In the writer's opinion a broader view of this subject should be taken. It should be admitted that, for successful working, water filters of all kinds must be handled with great care; and that either very fine or very coarse material, or a great deal of suspended matter of any kind, soon puts them out of service.

It was once thought that the structural elements of rapid water filters could be designed so that a simple combination and adjustment of them would fit them to any water. This view has had to be modified. Filters are not as elastic as they were formerly thought to be. The leading question to-day is not how to adapt filters to different waters, but how to adapt the different waters so that they can be handled by the filters.

The author has well said that the product of purification, and not the percentage of removal, should be the standard for judging the success of a plant. In this country an efficiency of 99% in removing bacteria is generally accepted as satisfactory evidence of a filter's capacity in this direction, and if the numbers of bacteria found in filter effluents do not exceed 200 per cubic centimeter, as determined by American methods, it is often contended that they should be con-

sidered satisfactory. This may or may not be all that should be demanded. Much depends upon the character of the impurities to be dealt with. If the filter is built to purify a water which is unpleasant to the sight and taste, and there is no special need of removing bacteria, one may be satisfied with a high percentage of removal and comparatively large numbers of bacteria in the effluent. If, on the other hand, as most often occurs, the purification plant is intended to remove color, turbidity and sewage bacteria, the standard by which the operation of the plant should be judged must be the amount of impurities in the water after treatment. As long as rivers and streams are regarded as natural sewers, into which all manner of wastes may be thrown without restriction, plants for the purification of drinking water derived from these streams should be built so as to remove practically all the bacteria. In accomplishing this end, it will be necessary to take into account many processes which were formerly considered to be preliminary or supplemental, and not indispensable to purification by filtration. The so-called preliminary processes include sedimentation and precipitation by chemicals. The processes by which water may be purified after passing through a filter are not as well known. The author has indicated one of them. Mr. Soper.

There seems to be good reason to believe that it will not long be beyond the range of practical expediency to sterilize public water supplies which it is not practicable to purify adequately by a single filtration. Many instances of late have served to call attention to sterilization. The question has been discussed before engineering societies in America, France and Germany, and before the International Congress of Hygiene and Demography. There are a great many official reports, monographs and journal articles at hand, in which the views of many scientific investigators have been expressed in favor of sterilization.

The sterilization of public water supplies is not a new idea. It was suggested by a member of the American Society of Civil Engineers in 1894, and the same gentleman wrote a paper on the subject before this Society at a later date. The process advocated was distillation. Basing an estimate, on the cost of distilling a supply of several million gallons of water per day, on an evaporative efficiency of 14.3 lbs. of water per pound of coal, it has been stated that the annual cost of supplying distilled water to a community of 40 000 people would not be in excess of $1 *per capita*. Since this estimate was given, improvements have been made in methods of evaporation, which would probably reduce the cost of producing very large volumes of distilled water. A plant erected for the United States Government at Fort Jefferson, Dry Tortugas, with a daily capacity of 90 000 galls., has developed on official trial an efficiency of 22.8 lbs. of water per pound of coal, the water in this case being salt.

Mr. Soper. The present outlook is not unfavorable for the use of chemical germicides for the sterilization of water on a large scale. The germicides are added in minute quantity, accomplish their result quickly and are removed from the water without in any way interfering with its attractiveness or hygienic qualities.

At first sight, the idea of killing the bacteria in water before drinking it appears to carry with it serious objections, but, upon considering the matter carefully, it will be evident that these are founded upon mere popular prejudices similar to those held against the use of chemical coagulants in rapid filtration. Arguments brought against the wholesomeness of sterilized water and food have, in the average case, but little scientific foundation. Sterilized food is a common article of commerce, and the enormous sale of canned goods, all of which are sterile and a very large proportion of which have been treated with chemicals to help flavor, color or preserve them, is increasing. Within recent years, a large demand has grown up for sterilized water and ice, so that there is hardly a city in this country, of 10 000 inhabitants or more, which has not a plant for the preparation of these conveniences.

Mr. Wiggin. T. H. Wiggin, Assoc. M. Am. Soc. C. E.—This paper presents to the speaker four more or less separate ideas which have an important bearing on the present design of slow sand filters.

1.—The main idea of the paper—that double slow filtration will produce an effluent having a constantly low number of bacteria at all seasons, and not merely a relatively low number of bacteria, as does single filtration.

2.—A suitable *schlammdecke* is only obtainable (in a reasonable time) by the application of raw water.

3.—At least 48 hours filtrate should be refiltered or wasted, being likely to contain an excessive number of bacteria.

4.—Ejector washers are not as economical as revolving washers.

The ideas will be referred to in different order, beginning with the third.

Of course, there is nothing new in the fact that the water filtered first is high in bacteria. The Germans have simply arrived at a higher standard than the Americans. Filtration, here, is in its infancy, and public sentiment is hardly educated to demand any filtration. At the same time it would add not a very large proportion to the cost to pump up and refilter, or waste, as may be most economical in the particular case, the first 48 hours' flow from newly scraped filters. If the shortest period between scrapings were ten days, it would take, at most, a plant of about one-quarter more capacity. Time will create a demand for this in this country. Perhaps engineers, even now, could carry it through in cases where filtration was finally adopted. The effect, on the average quality of the filtrate, of using the first part of

runs, evidently depends on the proportion of newly washed filters, and, ordinarily, the visible effect in a large plant would not be great. Mr. Wiggin.

Regarding the fourth idea, the speaker believes the Philadelphia results, and, still further, the results of some other plants now under construction or being planned, will change Mr. Goetze's views. He is evidently unaware of the present development whereby sand is washed and transported at the same time direct to its place in another filter, without storage or rehandling. The author does not give details of cost of washing or moving sand from the beds, and it may be that some of our present plants having ejector washers would compare favorably in the cost of the equivalent items for ejector washing. The total cost per million gallons ($1.52) is not so much less than the cost at Albany, for example, as to account for the great difference in wages. Only a detailed account of cost showing what items are included in Mr. Goetze's cost would enable this question to be decided.

Referring now to the first or main idea, of double slow filtration, there can be no dispute that this accomplishes "all that can reasonably be expected from water purification," at least, until the world has moved along a good deal. The question is, can it be accomplished more cheaply by another way? The speaker thinks there are very few cases in this country, like Bremen, in which the same area that is commonly allowed for single filtration will do for double filtration at times of high water. The only consumption tables the speaker has at hand are those of the Metropolitan Water District, in Massachusetts. The amounts for 1902 are as follows:

Millions of gallons per day.	Millions of gallons per day.	Millions of gallons per day.
Jan., 118	May, 106	Sept., 108
Feby., 117	June, 110	Oct., 106
March, 108	July, 108	Nov., 105
April, 103	Aug., 107	Dec., 125

It is evident that, in Boston, there is no great difference between the consumption in periods of high and low water. The author gives 63 to 100 mm. per hour, as the velocity in the preliminary filter, and 100 mm. or more, as the velocity in the final filter, or, say, a ratio of $\frac{3}{4}$ to 1. If the consumption in periods of high water were $\frac{1}{1+\frac{3}{4}}$, or 0.57 of that for which the filter plant were designed, then it would be possible to use double filtration at periods of high water without increasing the size of a plant designed for single filtration at the minimum rate mentioned. In cases where the consumption is practically constant, evidently about three-fourths more filter area would be required to use double filtration on the basis of the above rates.

The tendency of American ideas seems to be toward rough preliminary filtration at rates and by devices suggested by the American or

Mr. Wiggin. rapid system of filtration, though generally without the use of chemicals, with subsequent slow sand filtration at unusually high rates. This method would result in a comparatively cheap plant. The method of the author, doubtless, would not compare with it in cheapness. The question is, whether the American method can be relied upon to approach the German in effectiveness. The results of the Philadelphia and Harrisburg experiments would throw great light on the question, and their publication will be awaited with much interest. Even if this new method does not give quite as good results as double slow filtration, American cities, as a rule, are not ready for the additional cost which the author's method would entail.

Regarding the second idea, that raw water is required for a *schlammdecke*, this has a direct bearing on any double system of filtration. If the preliminary filtration is pretty complete in removing turbidity, it would seem reasonable that it might be desirable to have provision for admitting raw water to the newly scraped filters. A comparatively small pipe would do this, because only a small proportion, say one-tenth, of the filters would be using raw water at once. Information on the necessity of this provision, for the new American system of double filtration, from Philadelphia and Harrisburg, will be looked for with great interest.

Evidently, a little excess area in the final filters would be required for this method of applying raw water to furnish a *schlammdecke*, as a slow rate for the raw water in single filtration would be necessary; and a still further excess would be needed if the first filtrate were thrown away or admitted to the other filters, by the author's method, by pumping, or by any other method.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

JOHN BUTLER JOHNSON, M. Am. Soc. C. E.*

DIED JUNE 23D, 1902.

John Butler Johnson was born, on June 11th, 1850, of Quaker parentage, on a farm near Marlborough, in the northeastern part of Stark County, Ohio. He died fifty-two years afterward, June 23d, 1902, at his summer home at Pier Cove, near South Haven, on the east shore of Lake Michigan, having in that time won a very high place as an instructor in engineering and in the esteem of all who knew him.

The first sixteen years of his life were spent at home in the wholesome life of the farm. Meantime, he attended school at Marlborough, during one year at a high school of which Dr. T. C. Mendenhall was the principal. In 1860 the family—father, mother and seven children—moved to Kokomo, Indiana. Here, for a short time, he attended the Howard College, after which he attended the Holbrook Normal School at Lebanon, Ohio.

After this, four years were spent in teaching school at various points, mostly in Indiana, though for one term he had charge of a school in Arkansas. In 1872, when twenty-two years of age, he was called to Indianapolis, where he remained two years, as Secretary of the School Board and Instructor in the High School.

In 1874 he entered the University of Michigan, from which he was graduated in the civil engineering course in 1878. His next five years were spent in the practice of his new profession, the first three years on the Survey of the Great Lakes, the last two years as an Assistant Engineer of the Mississippi River Commission, with headquarters at St. Louis. A large part of this time was spent in field work, and he became quite expert as an instrumentman, particularly in the work of precise leveling.

In April, 1882, he became a Member of the Engineers' Club of St. Louis, in which he took a very active interest. In February, 1883, he was chosen Secretary of the Club.

In the autumn of 1883 he was called to the Chair of Civil Engineering in Washington University, at St. Louis, a position in which he succeeded Professor Charles A. Smith who had also preceded him as Secretary of the Engineers' Club. For his new work, Professor Johnson's experience had been a most admirable training, and he soon at-

* Memoir prepared by Robert Moore, Past-President, Am. Soc. C. E.

tained marked success. Few indeed have been his equals in the ability to interest and inspire his pupils.

During the sixteen years in which he remained at Washington University, Professor Johnson, who was a tireless worker, found time for the writing of the books which have made his name familiar to all students of engineering. The magnitude and importance of his work as an author is shown by the following list of his books given in the order of their first publication:

1.—In 1885, "Topographical Surveying by means of the Transit and Stadia."

2.—In 1886, "The Theory and Practice of Surveying." This is one of the best books of its kind, and numerous editions have been called for.

3.—In 1892, "The Theory and Practice of Modern Framed Structures," a quarto book, of 525 pages, on bridges and roofs, in the preparation of which he was assisted by Professor F. E. Turneaure and Mr. C. W. Bryan.

4.—In 1895, "Engineering Contracts and Specifications." As a preparation for this work, Professor Johnson attended a course of lectures at the University Law School.

5.—In 1897, "Materials of Construction," in which were embodied the results of a large amount of work done by him in the testing laboratory of the University.

In addition to the labor of writing these books, to say nothing of numerous professional papers and addresses, he did a large amount of work upon the "Index to Current Engineering Literature" published by the *Journal* of the Association of Engineering Societies. Of this index, which is of great value to engineers and engineering students, Professor Johnson was the originator and the manager from October, 1884, to December, 1895, when the work was taken up and continued by the *Engineering Magazine*.

From 1892 to 1895 he was engaged in making investigations of the strength of timber for the Division of Forestry of the United States Department of Agriculture. The results of these investigations, some of which were important, are embodied in several bulletins of the Department.

Professor Johnson was one of the founders, for two years the first Secretary, and for one year President of the Society for the Promotion of Engineering Education, organized in 1893. In 1895 he took an active part in the formation of the St. Louis Railway Club, a large and flourishing organization of men engaged in railway operation, and was a member of the Executive Committee until his removal from St. Louis.

In 1899, after sixteen years of service at Washington University, he accepted an appointment as Dean of the Engineering School of the

University of Wisconsin, at Madison. His life there was a continuation of that at St. Louis, a life of diligent, faithful and highly successful work. Under his leadership the Engineering School at Madison took fresh life and grew as it never had done before. Meantime, he, himself, became an important factor in the life of the University and in the city of his adoption. Everything, indeed, pointed to a long career of distinguished usefulness, when all was ended suddenly by his untimely death.

Professor Johnson, on May 3d, 1892, became a Member of the Institution of Civil Engineers, of Great Britain. On March 14th, 1899, he was elected a Member of the Western Society of Civil Engineers, and thereafter until his death took a very active part in its work. He was also a member of the American Society of Mechanical Engineers; the International Association for Testing Materials; the American Association for the Advancement of Science; the Academy of Science, of St. Louis; the Art Club of Madison, and the University Co-operative Association. He was also a very earnest and active member of the Unitarian Church, of Madison, as he had formerly been of the Church of the Unity (Unitarian), at St. Louis.

In 1878, the year of his graduation from the University of Michigan, he was married to Miss Phebe Henby, who, with three daughters and two sons, survives him.

The large work accomplished by Professor Johnson is proof of the untiring industry and devotion to duty which always characterized him. What his hand found to do, he did with his might.

As a teacher he had few equals. He not only knew his subject himself, but he knew how to impart his knowledge and to help his pupils so that they should thereafter need no help.

Outside of his special work he was ever mindful of his duties to the city, to the State and the world. He was a good citizen, a valiant fighter against ignorance and evil. He was faithful to every duty, whether private or public; a man whose death is a loss to all men.

Professor Johnson was elected a Member of the American Society of Civil Engineers on April 7th, 1886. In 1899 he presented a paper* entitled "Cast Iron—Strength, Resilience, Tests, and Specifications," and was a frequent contributor to the discussions in the *Transactions* of the Society.

**Transactions*, Am. Soc. C. E., Vol. XXII, p. 91.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 10.

DECEMBER, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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Papers and Discussions.....Pages 1099 to 1179.

NEW YORK 1903.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS in the office of the Librarian of Congress, at Washington.

American Society of Civil Engineers.

OFFICERS FOR 1903.

President, ALFRED NOBLE.

Vice-Presidents.

Term expires January, 1904:	*Term expires January, 1905:*
CHARLES C. SCHNEIDER,	L. F. G. BOUSCAREN,
JOHN R. FREEMAN.	JAMES D. SCHUYLER.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1904:	*Term expires January, 1905:*	*Term expires January, 1906:*
JOSIAH A. BRIGGS,	RICHARD S. BUCK,	ALFRED CRAVEN,
GEORGE F. SWAIN,	GEORGE H. PEGRAM,	JOSEPH O. OSGOOD,
EMIL KUICHLING,	WILLIAM J. WILGUS,	GEORGE S. DAVISON,
MORDECAI T. ENDICOTT,	WILLIAM JACKSON,	E. C. LEWIS,
EDWARD C. CARTER,	EDMUND F. VAN HOESEN,	HUNTER McDONALD.
FRANK C. OSBORN.	JAMES L. FRAZIER.	ELWOOD MEAD.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOSIAH A. BRIGGS,	GEORGE H. PEGRAM,	CHARLES C. SCHNEIDER,
L. F. G. BOUSCAREN,	ALFRED CRAVEN,	MORDECAI T. ENDICOTT,
GEORGE F. SWAIN,	JOSEPH O. OSGOOD,	EMIL KUICHLING,
RICHARD S. BUCK,	FRANK C. OSBORN,	WILLIAM JACKSON,
WILLIAM J. WILGUS.	GEORGE S. DAVISON.	CHARLES WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

ON RAIL SECTIONS:—G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 533 Columbus
CABLE ADDRESS, - - - - "Ceas, New York."

Vol. XXIX. DECEMBER, 1903. No. 10.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

December 2d, 1903.—The meeting was called to order at 8.40 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 93 members and 11 guests.

The minutes of the meetings of November 4th and 18th, 1903, were approved as printed in *Proceedings* for November, 1903.

A paper by S. Maximoff, Assoc. M. Am. Soc. C. E., entitled "A Desirable Method of Dredging Channels through River Bars," was presented by the Secretary, who also read a communication on the subject from Rudolph Hering, M. Am. Soc. C. E.

The paper was discussed verbally by Messrs. E. L. Corthell, A. W. Robinson, H. J. Howe, Edward P. North and D. E. Moran.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Thomas Walker Fowler, Melbourne, Victoria, Australia.
Hubert Edward Green, San Francisco, Cal.
William Storrs MacHarg, Chicago, Ill.
John McNeal, Jr., Easton, Pa.
Florian Gaie Ross, Pittsburg, Pa.
Reginald Heber Thomson, Seattle, Wash.
Charles Beatty Wilson, Tullahoma, Tenn.
Andrew Feaster Woolley, Mexico, Mexico.

As Associate Members.

Joseph Hockman Bowman, Tonalá, Chiapas, Mexico.
Edward Sylvester Brower, Brooklyn, N. Y.
Arthur Ira Campbell, Osceola, Ark.
William Eliot Hamlin, New York City.
Charles Warren Murray, Americus, Ga.
Julius Welch Pfau, South Schenectady, N. Y.
Edgar Maverick Smith, Chicago, Ill.
Sutton Van Pelt, Tidewater, Ala.
Samuel Daugherty Williams, Jr., Toledo, Ohio.
James Albert Woodruff, West Point, N. Y.
Henry Amerman Young, Fort Washington, Md.

The Secretary announced the transfer of the following candidates, by the Board of Direction, on December 1st, 1903, from the grade of Associate Member to the grade of Member:

As Members.

Frederick Albert Coleman, Belington, W. Va.
John Lyle Harrington, West New Brighton, N. Y.
Kingsley Leverich Martin, Brooklyn, N. Y.
Charles William Smith, New York City.
Bernard Matthew Wagner, Brooklyn, N. Y.
Irving Mason Wolverton, Mt. Vernon, Ohio.

The Secretary announced the election of the following candidates by the Board of Direction, on December 1st, 1903:

As Juniors.

Sylvanus A Becker, Connellsville, Pa.
John Harrison Foss, Huelo, Maui, Hawaii.
John Blake Gordon, Washington, D. C.
Guy Scott, Columbus, Ohio.
Charles Wood Sutton, Union, Ore.
Howard Shay Williams, Boonton, N. J.
Henry Wright Woodcock, Brooklyn, N. Y.
Tuck Ching Strong Yen, Shanghai, China.

Adjourned.

December 16th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 107 members and 9 guests.

A paper, by Emile Low, M. Am. Soc. C. E., entitled "The Breakwater at Buffalo, New York," was presented by the Secretary, who also read communications on the subject from Messrs. G. H. Raymond, Thomas D. Pitts, William T. Lyle and George E. Fell.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

December 1st, 1903.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Buck, Craven, Croes, Davison, Osgood, Pegram, and Schneider.

The Secretary reported that the Committee appointed, on the recommendation of this Society, by the authorities of the St. Louis Exposition, 1904, to organize an International Congress of Engineering, had made every effort to secure the co-operation of the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers, and the Society for the Promotion of Engineering Education, and of those Bureaus of the Department of War, and the Department of Commerce and Labor, in charge of Military Engineering; but as the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers declined to co-operate in the project, the Committee had decided to report its inability to organize the proposed Congress, and had so reported to the authorities of the Exposition.

The Committee on Publications, and the Secretary, were appointed as a Committee to prepare for the Convention of the Society on an International Basis.

Applications were considered and other routine business transacted.

Six candidates were transferred from the grade of Associate Member to that of Member, and eight candidates for admission were elected to the grade of Junior.*

Adjourned.

* See pages 438 and 439.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, January 6, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Theory of the Spherical Dome with a Homogeneous Surface, and of the Framed Dome; Also Notes on the Construction of Masonry and Metal Domes," by E. Schmitt, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL MEETING.

The Fifty-first Annual Meeting will be held at the Society House, January 20th and 21st, 1904. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The annual reports will be read, officers for the ensuing year elected, and members of the Nominating Committee appointed. The proposed project for a Union Engineering Building, and the proposition to appoint a Special Committee on "Concrete and Steel-Concrete," will also be part of the order of business.

Arrangements for the excursions and entertainments have been placed in the hands of the following committee:

J. WALDO SMITH,
S. L. F. DEYO, CHAS. WARREN HUNT.

NOMINATING COMMITTEE.

The Constitution provides that at the Annual Meeting of each year, seven Corporate Members, not officers of the Society, one from each of the seven geographical districts, into which the Society is divided for this purpose, shall be appointed by the meeting to serve for two years.

The usual blank request for suggestions as to representatives of each district, for presentation to the meeting, has been mailed to Corporate Members.

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

A Committee of the Board of Direction is now arranging a programme, with a view to making this Convention an International Meet-

ing of Engineers, for the presentation and discussion of timely subjects of professional interest.

As the details of the arrangements are developed, they will be announced in *Proceedings*.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an Engineering Exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

ROBERT MOORE, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
EDWARD C. CARTER, M. Am. Soc. C. E., Chicago, Ill.
MORDECAI T. ENDICOTT, M. Am. Soc. C. E., Washington, D. C.
JAMES L. FRAZIER, " " Frankfort, Ind.
WILLIAM JACKSON, " " Boston, Mass.
EMIL KUICHLING, " " New York, N. Y.
JOHN F. WALLACE, " " Chicago, Ill.
H. J. PFEIFER, Assoc. M. Am. Soc. C. E., St. Louis, Mo., *Secretary.*

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ACCESSIONS TO THE LIBRARY.

From November 11th to December 8th, 1903.

DONATIONS.*

MODERN LOCOMOTIVE PRACTICE.

A Treatise on the Design, Construction, and Working of Steam Locomotives. By C. E. Wolff, A. M. Inst. C. E. Cloth, 9 × 6 ins., 8 + 267 + 5 pp., illus. Manchester, The Scientific Publishing Company. 10 shillings, 6 pence, net.

In this book the first chapter contains a short discussion of the resistances to be overcome by the locomotive, and the chapters which follow are arranged in what appears to the author to be the natural order. Two chapters are devoted to the discussion of the different general types in use in Great Britain, and then follow ten chapters dealing with the different parts in detail. The design of link motions and of radial valve gears has been treated at considerable length, and a new method of working out accurately a link motion described. A similar method is adopted for the working out of Joy's valve gear, and a calculation given of the maximum value of the stresses in the connecting rod due to the inertia of this gear. All the drawings have been reproduced from actual working drawings. The Contents are: Introduction—Train Resistance; Types of Express Locomotives; Goods and Mineral Engines; The Locomotive as a Carriage; Boilers; Cylinders; Valve Motions; Radial and Single Eccentric Valve Gears; Connecting Rods; Crossheads and Slides; Crank Axles; Balancing; Wheels; Examples of Modern Locomotives; Slipping of Locomotives at High Speeds. There is an index of five pages.

IRRIGATION ENGINEERING.

By Herbert M. Wilson, M. Am. Soc. C. E. Fourth Edition. Revised and Enlarged. Cloth, 9 × 6 ins., 23 + 573 pp., illus. N. Y., John Wiley & Sons, 1903. $4.00.

The author states in the preface that since the issue of the second edition there have been few important developments in hydraulic engineering, consequently the present revision does not affect any portion of the book radically, though it has been sufficiently thorough to affect every portion more or less. There have been constructed recently a number of great storage dams, both of masonry and of loose rock, and important changes in existing structures have been made. These are noted in Part III, in which the greatest amount of textual change has been made. The chapter on subsurface water sources has been improved materially. The chapter on rainfall and run-off of streams has been brought up to date and extended. The Contents are: Precipitation, Runoff, and Stream Flow; Evaporation, Absorption, and Seepage; Alkali, Drainage, and Sedimentation; Quantity of Water Required; Flow and Measurement of Water in Open Channels; Sub-surface Water Sources and Sewage for Irrigation; Classes of Irrigation Works; Alignment, Slope, and Cross-Section; Headworks and Diversion Weirs; Scouring Sluices, Regulators, and Escapes; Falls and Drainage Works; Distributaries; Application of Water, and Pipe Irrigation; Location and Capacity of Reservoirs; Earth and Loose-Rock Dams; Masonry Dams, Wasteways and Outlet Sluices; Pumping, Tools and Maintenance; Tables. There is an index of thirty-three pages.

THE DESIGN OF STEEL MILL BUILDINGS AND THE CALCULATION OF STRESSES IN FRAMED STRUCTURES.

By Milo S. Ketchum, Assoc. M. Am. Soc. C. E. Cloth, 9 × 6 ins., 13 + 367 pp., illus. New York, The Engineering News Publishing Co., 1903. $4.00.

This book is intended to provide a short course in the calculation of stresses in framed structures, and give a brief discussion of mill-building construction. It is to supplement the elementary books on stresses, on one hand, and the more elaborate treatises on bridge design, on the other. While the book is concerned chiefly with mill buildings, much of the matter will apply equally well to all classes of steel-frame construction. Both the algebraic and graphic methods of calculating stresses are described and illustrated. In the discussion of mill-building construction, the aim has been to describe the methods of construction and the material used, together with a brief treatment of mill-building design, and the making of estimates of weight and cost. The Contents are: Dead Loads; Snow Loads; Wind Loads; Miscellaneous Loads; Graphic Statics; Stresses in Framed Structures; Stresses in Simple Roof Trusses;

* Unless otherwise specified, books in this list have been donated to the Library by the Publishers.

Simple Beams; Moving Loads on Beams; Stresses in Bridge Trusses; Stresses in a Transverse Bent; Stresses in Portals; Stresses in Three-Hinged Arch; Stresses in Two-Hinged Arch; Combined and Eccentric Stresses; General Design; Framework; Corrugated Steel; Roof Coverings; Side Walls and Masonry Walls; Foundations; Floors; Windows and Skylights; Ventilators; Doors; Shop Drawings and Rules; Paints and Painting; Estimate of Weight and Cost; Miscellaneous Structures. There is an index of five pages.

FRICTION AND LUBRICATION.

A Hand-Book for Engineers, Mechanics, Superintendents and Managers. By William M. Davis. Cloth, 8 × 6 ins., 225 pp., illus. The Lubrication Publishing Co., Pittsburg, Pa., 1903. $2.00.

The author, for the past ten years, has been in a position to make a close study of lubrication, on many kinds of engines and machinery, under all sorts of conditions. In presenting this book to the notice of those who have to do with the use of lubricants, while he has not endeavored to exploit any new theories, he has kept in mind the fact that engineers, managers and mechanics are busy men, and, therefore, he has tried to present the matter in a plain, concise way that will be readily understood by readers and be of practical value in their every-day work. Some of the chapter headings are: Friction; Friction Losses; Theory of Lubrication; Testing of Oils; Cylinder and Valve Lubrication; Lubricating Appliances; Care of Sight Feed Lubricators; Cutting and Scoring of Cylinder Surfaces; Groaning of Pump and Engine Valves; Deposits of Sticky and Solid Substances in Steam Cylinders; Effects of Some Boiler Compounds on Cylinder Lubrication; Lubrication of Gas and Gasoline Engines; Oiling Devices; Grease; Bearings and Journals; Hot Bearings and their Treatment; Ball and Roller Bearings; Oil House Methods, Cost, etc. There is an index of nine pages.

Gifts have also been received from the following:

Am. Electrochemical Soc. 1 bound vol.
Assoc. of Ontario Land Surv. 3 pam.
Baltimore & Ohio R. R. Co. 1 pam.
Baltimore, Chesapeake & Atlantic Ry. Co. 3 pam.
Buffalo, N. Y.—Bureau of Water. 8 vol., 2 pam.
Buffalo & Susquehanna R. R. Co. 2 pam.
Canada—Supt. of Immigration. 1 vol.
Chicago & Eastern Ill. R. R. Co. 1 pam.
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Cincinnati, Hamilton & Dayton Ry. Co. 1 pam.
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Colliery Guardian Co. Ltd. 1 pam.
Conn.—State Board of Health. 3 bound vol., 1 vol.
Corthell, E. L. 1 pam.
Denver, Colo.—Bureau of Health. 21 pam.
Detroit & Mackinac Ry. Co. 1 pam.
Fisk, W. L. 1 pam.
Gloucester, Mass.—City Clerk. 1 bound vol.
Great Britain—Patent Office. 1 vol., 8 pam.
Gulf & Ship Island R. R. Co. 1 pam.
Harvard Univ. 2 bound vol.
Hubbell, C. W. 1 pam.
Ill.—Bureau of Labor Statistics. 1 bound vol.
Ind.—Dept. of Geology & Natural Resources. 2 bound vol.
Inst. of Engrs. & Shipbuilders. 1 bound vol.
Inst. of Marine Engrs. 1 bound vol.
Interurban Street Ry. Co. 1 pam.
Japan—Imperial Earthquake Investigation Committee. 7 pam.
League of Am. Municipalities. 1 vol.
Lillibridge, Ray D. 1 pam.
Master Car Builders' Assoc. 1 bound vol.
Mayne, Charles. 10 vol.
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Morison, R. L. 1 bound vol.
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Newark, N. J.—Document Clerk. 1 bound vol.
Platt, T. C. 6 pam.
Poor's R. R. Manual Co. 1 bound vol.
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Reading, Pa.—Water Dept. 1 bound vol.
Royal Philosophical Soc. of Glasgow. 1 vol.
Rust, C. H. 1 bound vol.
Ruttan, H. N. 1 pam.
St. Louis Southwestern Ry. Co. 1 pam.
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U. S. Bureau of Steam Eng. 1 pam.
U. S. Commr. of Patents. 1 pam.
U. S. Copyright Office. 1 pam.
U. S. Navy Dept. 10 pam.
U. S. Patent Office. 1 vol.
Univ. of California. 1 vol.
Univ. of Ill. Agri. Exper. Station. 2 pam.
Wabash R. R. Co. 2 pam.
Wisconsin Central Ry. Co. 2 pam.
Yazoo & Mississippi Valley R. R. Co. 2 pam.

BY PURCHASE.

Cours d'Électricité. Théorique et Pratique. Par C. Sarazin. Deuxième Edition, Revue et Augmentée. Paris, E. Bernard & Cie, 1903.

Die Telegraphie ohne Draht. Von Augusto Righi und Bernhard Dessau. Braunschweig, Friedrich Vieweg und Sohn, 1903.

Gas-Engine Design. With an Introduction on Comprsssed Air. By E. J. Stoddard. Parker & Burton, Detroit.

Acetylene: The Principles of its Generation and Use. A Practical Handbook on the Production, Purification, and Subsequent Treatment of Acetylene for the Development of Light, Heat and Power. By F. H. Leeds and W. J. Atkinson Butterfield. London, Charles Griffin and Company, 1903.

Hydraulics with Working Tables. By E. S. Bellasis, M. Inst. C. E. Rivingtons, London, 1903.

SUMMARY OF ACCESSIONS.

November 11th to December 8th, 1903.

Donations (including 18 duplicates)	178
By purchase	5
Total	183

MEMBERSHIP.

ADDITIONS.

MEMBERS.		Date of Membership.
ALBERTSON, CHARLES. Sub-Agt. and Mgr., Eng. Dept., The Am. Trading Co., 99 Kitamachi, Kobe, Japan	Jun.	Oct. 1, 1895
	Assoc. M.	Mar. 1, 1899
	M.	Oct. 7, 1903
BASSELL, BURR. Kernville, Cal.		Nov. 4, 1903
CLARK, JOHN HOWARD. 45 Lincoln St., Malden, Mass		Nov. 4, 1903
DIXON, CHARLES YOUNG. U. S. Asst. Engr., Amherstburg, Ont., Canada		Nov. 4, 1903
DUNHAM, LEWIS AUGUSTUS. 404 New England Bldg,, Kansas City, Mo		June 3, 1903
HARRINGTON, JOHN LYLE. C. W. Hunt Co., West New Brighton, N. Y.	Jun.	Aug. 31, 1897
	Assoc. M.	Oct, 4, 1899
	M.	Dec. 1, 1903
HOLMES, HOWARD CARLETON. Chf. Engr., San Francisco Dry Dock Co., San Fran., Oakland & San Jose R. R., Room 12, Ferry Bldg., San Francisco, Cal.		Nov. 4, 1903
JONAH, FRANK GILBERT. Chf. Engr., St. L., Brownsville & Mex. Ry., Corpus Christi, Tex.		Nov. 4, 1903
MCNEAL, JOHN, Jr, Asst. Engr., Lehigh Coal & Nav. Co., 507 Drake Bldg., Easton, Pa.		Dec. 2, 1903
MARTIN, KINGSLEY LEVERICH. Asst. Engr., Dept. of Bridges, New York City, 84 Broadway, Brooklyn, N. Y.	Jun.	Nov. 5, 1895
	Assoc. M.	May 3, 1899
	M.	Dec. 1, 1903
POLLEDO, YSIDORO. Manzaneda 16, Matanzas, Cuba	Jun.	Jan. 2, 1889
	M.	Nov. 4, 1903
SMITH, CHARLES WILLIAM. Chf. Engr., O'Rourke Eng. Constr. Co., 26 Nassau St., New York City	Assoc. M.	Apr. 5, 1893
	M.	Dec. 1, 1903
THORNHILL, EDWARD BAYLIES. Chf. Engr., L. & N. W. Ry., Euston Station, London, England		Oct. 7, 1903
UHLIG, CARL. Asst. Engr. and Chf. Draftsman, Board of State Harbor Commrs., Room 16, Ferry Bldg,, San Francisco, Cal.		Oct. 7, 1903
WAGNER, BERNARD MATTHEW. Asst. Engr., Dept. of Water Supply, Gas and Electricity, City of New York (Res., 257 East 12th St., Flatbush, Brooklyn), N. Y.	Assoc. M.	May 3, 1899
	M.	Dec. 1, 1903
WENDT, EDWIN FREDERICK. Asst. Engr., Pitts. & Lake Erie R. R., Terminal Station, Pittsburg, Pa.		Oct. 7, 1903
WILLIAMS, CHAUNCEY GRANT. 25 Clinton St., Brooklyn, N. Y.	Assoc. M.	Feb. 6, 1895
	M.	Oct. 7, 1903
WILSON, CHARLES BEATTY. Bridge Superv., N. C. & St. L. Ry., P. O. Box 33, Tullahoma, Tenn.		Dec. 2, 1903

		Date of Membership.
WOLVERTON, IRVING MASON. Chf. Engr., The Mt. Vernon Bridge Co., Mt. Vernon, Ohio....	Assoc. M.	Dec. 4, 1895
	M.	Dec. 1, 1903
WOOLLEY, ANDREW FEASTER. Calle Damas 131, Tampico, Mexico.....		Dec. 2, 1903

ASSOCIATE MEMBERS.

BROWER, EDWARD SYLVESTER. Asst. Engr., Brooklyn Heights R. R. Co., 164 Montague St., Brooklyn, N. Y.....		Dec. 2, 1903
PRITCHETT, CHARLES MARCELLUS. Asst. Engr., U. S. Geological Survey, Washington, D. C....		Sept. 2, 1903
SIMPSON, ERASTUS ROLAND. Engr. and Gen. Mgr., Mech. Dept., Chapman Double Ball Bearing Co., Ltd., 39 Pearl St., Toronto, Ont., Canada.....		Nov. 4, 1903
VAN PELT, SUTTON. U. S. Engr. Office, Tuscaloosa, Ala.....	Jun.	Mar. 6, 1900
	Assoc. M.	Dec. 2, 1903
WENTWORTH, CHARLES AUSTIN. Civ. Engr., U. S. N., 1437 Rhode Island Ave., Washington, D. C.....		Oct. 7, 1903
WILLIAMS, SAMUEL DAUGHERTY, Jr. Chf. Engr., The Toledo Ry. & Terminal Constr. Co., 201 Terminal Station, Toledo, Ohio.....		Dec. 2, 1903
WOODRUFF, JAMES ALBERT. 1st Lieut., Corps of Engrs., U. S. A., West Point, N. Y.....		Dec. 2, 1903
YOUNG, HENRY AMERMAN. In Chg. of Constr. Work for U. S. Engr. Dept. at Ft. Washington, Md., and at Ft. Hunt, Va. Address, U. S. Engr. Office, Fort Washington, Md.	Jun.	Mar. 5, 1901
	Assoc. M.	Dec. 2, 1903

ASSOCIATES.

OLLS, WILLIAM CLARENCE. Box 739, Erie, Pa.....		Nov. 3, 1903
WILCOCK, FREDERICK. 862 Fiftieth St., Brooklyn, N. Y.....	Jun.	Jan. 7, 1902
	Assoc.	Oct. 6, 1903

JUNIORS.

GAY, ROBERT WALTER. 425 Avenue E, Bayonne, N. J.....	Oct. 6, 1903
GORDON, JOHN BLAKE. 6 Cooke Pl., N. W., Washington, D. C.	Dec. 1, 1903
GRISWOLD, HARRY TODD. Old Lyme, Conn.....	Oct. 6, 1903
HANCOCK, HENRY SYDNEY, Jr. 627 Cooper St., Camden, N. J..	Oct. 6, 1903
SCOTT, GUY. Union Station, Columbus, Ohio.....	Dec. 1, 1903
WEBSTER, ROYAL SYLVESTER. 3755 Washington St., Kansas City, Mo	Oct. 6, 1903
WILLIAMS, HOWARD SHAY. Box 522, Boonton, N. J.....	Dec. 1, 1903
WOODCOCK, HENRY WRIGHT. Asst. Insp., Brooklyn Heights R. R. Co., 2431 Church Ave., Brooklyn, N. Y.....	Dec. 1, 1903

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(November 11th to December 8th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris. France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.

LIST OF ARTICLES.

Bridge.

Concrete Bridge over the Big Muddy River, Illinois Central R. R.* H. W. Parkhurst, M. Am. Soc. C. E. (13) Nov. 12.
The Protection of Steel in Ballasted Floor Bridges.* (13) Nov. 12.
Armoured Concrete Foot-Bridge at Toulouse.* (12) Nov. 13.
Standard Short-Span Bridges on the Atchison, Topeka & Santa Fe Railway.* (14) Nov. 14.
A Comparison of the Requirements of Recent Railway Bridge Specifications. A. H. Heller. (13) Nov. 19.
An American Bridge Built of German Steel and Launched at a Shipyard.* P. S. Hildreth. (13) Nov. 19.
The Limits of Working Stress in Bridges. (12) Serial beginning Nov. 20.
Comparative Eye-Bar and Wire Cable Designs for a Highway Bridge over the Rhine at Cologne.* (15) Nov. 20.
The Ambridge Plant of the American Bridge Company.* (14) Serial beginning Nov. 21.
Ballasted Floors on the Atchison, Topeka & Santa Fe (bridge floors).* (40) Nov. 27.
The Coatesville Viaduct of the Pennsylvania Railroad.* (40) Nov. 27.
Eye-Bars or Cables for Manhattan Bridge. R. S. Buck. (15) Dec. 4.
The Manhattan Bridge over the East River, New York.* (15) Dec. 4.
Erection of the Turtipar Bridge on Barges and Cantilever Falsework. (14) Dec. 5.
Le Pont Suspendu de Vernaison, sur le Rhône.* Léon Griveaud. (35) Nov.
Ponts à Transbordeur.* G. Leinekugel Le Cocq. (33) Serial beginning Nov. 21.

Electrical.

The Heyland Induction Motor.* A. S. Langsdorf. (Paper read before the Engineers' Club of St. Louis.) (1) Sept.
The Electrical Equipment of a Gold Dredge.* Ralph L. Montagu. (42) Oct.
The Cathode Ray Alternating Current Wave Indicator.* Harris J. Ryan. (42) Oct.
The Factors Which Affect the Energy Losses in Armature Cores.* J. Walter Esterline and C. E. Reid. (42) Oct.
Central Station Economies. W. E. Goldsborough and P. E. Fansler.* (42) Oct.
The Legalized Standard of Electromotive Force. Henry S. Carhart. (42) Oct.
Magnetic Units and Other Subjects That Might Occupy Attention at the Next International Electrical Congress. A. E. Kennelly. (42) Oct.
Electric Motors for Centrifugal Pumps and Fans. Aug. J. Bowie, Jr. (42) Oct.
An Efficient High-Pressure Water-Power Transmission Plant.* George J. Henry, Jr., and Joseph N. Le Conte. (42) Oct.
The E. C. A. Proposed Model Wiring Specification. (26) Nov. 6.
Single-Phase Motors for Traction. Giorgio Finzi. (26) Serial beginning Nov. 6.
Reversing Motors for Live Rollers.* (22) Nov. 6.
Recent Developments of the Metropolitan Electric Supply Co.'s Installations.* (26) Serial beginning Nov. 13.
On the Use of Capacities as Multipliers in Connection with Electrostatic Voltmeters on Alternating-Current Circuits. E. W. Marchant and G. W. Worrall. (Abstract of Paper read before the British Assoc. for the Advancement of Science.) (26) Nov. 13.
Notes on the Theory of Parallel Running of Synchronous Machinery. H. C. Leake. (26) Nov. 13.
An Unusual Form of Capillary Electrometer.* Emile Guarini. (19) Nov. 14.
Electric Pumping Plant for De Beers Consolidated Mines, Kimberley.* (26) Nov. 13; (47) Nov. 14.
Faure Type Accumulators. (19) Nov. 14.
Distribution of Current in Three Phase Systems.* F. Hardie Jeannin. (27) Nov. 14.
Calculation of the Apparent Inductance of Armature Coils.* C. C. Hawkins. (27) Serial beginning Nov. 14.
The Relative Reliability of Wireless and Wire Telegraph Systems.* Reginald A. Fessenden. (27) Nov. 14.
New Generating Station of the Rochester Gas and Electric Company.* (27) Nov. 14.
The Design of Direct-Current Machinery.* Val. A. Fynn. (26) Serial beginning Nov. 20.
The Choice of Wattmeters. Paul MacGahan. (27) Nov. 21.
Transposition of Telephone Lines: Cross-Talk and Induction.* Frank F. Fowle. (Abstract of Paper read before the Assoc. of Ry. Telegraph Supts.) (27) Nov. 21.
Surveys for Electrolysis, and Their Results.* D. H. Maury. (24) Nov. 23.
The Greenhill Electricity Works, Oldham Corporation.* (26) Serial beginning Nov. 27.
The Edison Accumulator for Automobiles.* W. Hibbert. Assoc. M. Inst. E. E. (Paper read before the Inst. of Elec. Engrs.) (26) Serial beginning Nov. 27.
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Testing Alternators under Full Load Conditions.* W. L. Waters. (27) Nov. 28.
Wireless Fire Alarm Signalling Apparatus.* (27) Nov. 28.
Recent Progress Abroad in Wireless Telephony.* (27) Nov. 28.
Large Gas Engine Electrical Plant in Germany.* (27) Nov. 28.
The Murphy High Potential Interrupter.* A. Frederick Collins. (27) Nov. 28.

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Notes on Certain Three-Wire Systems.* Charles T. Mosman. (47) Nov. 28.
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A Central Electric Power Plant of the Coal-Mining Department of the Delaware, Lackawanna & Western Railroad Co., at Scranton.* H. M. Warren. (45) Dec.
Recent Developments in Niagara Power.* H. W. Buck. (10) Dec.
Electric Convection. J. Frank Meyer. (3) Dec.
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Recent English Alternating Current Machines.* (17) Dec. 5; (27) Dec. 5.
Montreal, the Greatest Centre of Transmitted Power.* Alton D. Adams. (27) Serial beginning Dec. 5.
Methods of Signaling and Operating in Telephone Exchanges.* Kempster B. Miller and Charles S. Winston. (27) Serial beginning Dec. 5.
Telephone Transmitters.* Arthur V. Abbott. (27) Serial beginning Dec. 5.
Usine Hydro-Électrique d'Avignonnet sur le Drac (Isère). A. Dumas. (33) Nov. 14.
La Construction des Dynamos en Allemagne.* C. F. Guilbert. (36) Serial beginning Nov. 25.

Marine.

The Economy of Large Ships. A. W. Robinson, M. Can. Soc. C. E. (5) Vol. 16, Pt. 2.
The Stone-Lloyd System of Ship's Bulkhead Gear. (11) Nov. 6.
Oil-Motor Boat for the Uganda Railway Company.* (11) Nov. 6.
The Carena Dry-Dock, Argentine Republic.* (14) Nov. 14.
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The Submarine Boat Protector.* (12) Nov. 20.
The Boilers of the *Maine*. (Favorable report on Niclausse Water Tube Type. (20) Nov. 26.
Non-Corrosive Nickel-Steel Boiler Tubes. Albert Ladd Colby, M. Am. Soc. M. E. (Paper read before the Soc. of Naval Archts. and Marine Engrs.) (13) Nov. 26.
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Notes on Side-Launchings. Wm. G. Groesbeck. (Paper read before the Soc. of Naval Archts. and Marine Engrs.) (13) Dec. 3.

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The Cost of Open-Hearth Steel as Affected by Using Blast Furnace Gas in Gas Engines. Peter Eyermann. (Paper read before the Civ. Engineers' Club of Cleveland.) (1) Sept.; Abstract (22) Nov. 6.
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An Economizer Discussion. (Fuel Economizers for Power Stations.) Edwin B. Katte, A. H. Blackburn, Wm. Downs, R. D. Tomlinson and J. E. Moulthrop. (65) Nov. 1.
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The Pitting Rust of Iron. W. H. Birchmore. (24) Nov. 16.
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The Economic Advantages of Working a Carburetted Water-Gas Plant in Conjunction with a Coal-Gas Plant. S. Carpenter. (Paper read before the Southern District Assoc. of Gas Engrs. and Mgrs.) (66) Nov. 17.
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The Ambridge Plant of the American Bridge Company.* (14) Serial beginning Nov. 21.

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An Apparatus for Measuring Gas Leakage.* Emile Guarini. (13) Nov. 26.
Band Brakes.* J. S. V. Bickford. (12) Nov. 27.
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The Hydraulic Plant for Drawing Steel Shells, at the Imperial Arsenal, Osaka, Japan.* Gompei Kuwada. (14) Nov. 28.
Superheated Steam.* F. J. Rowan. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning Nov. 28.
The Science of Steam Generation.* F. J. Rowan, Assoc. M. Inst. C. E. (10) Dec.
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Electrolytic Copper Refining. Wilder D. Bancroft. (Abstract of Paper read before the Amer. Electrochemical Soc.) (16) Nov. 14.

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Lead Smelting in Spain.* Hjalmar Eriksson. (16) Nov. 14.
Grinding Machines Used at Kalgoorlie. W. E. Simpson. (Abstract of Paper read before the Inst. of Min. and Metal.) (16) Nov. 14.
Manganese Ore as a Desulphurizing Agent in the Foundry. (20) Nov. 19.
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Treatment of Telluride Ores by Dry-Crushing and Roasting, at Kalgoorlie, Western Australia.* W. Evan Simpson. (Paper read before the Inst. of Min. and Metal.) (68) Serial beginning Nov. 7; Abstract (16) Nov. 21.
Manufacture of Sound Casting by Means of Thermit. J. B. Nau. (62) Nov. 26.
Consumption of Zinc in Cyanide Plants. Walter H. Virgoe. (Abstract of Paper in the *Journal of the Chemical, Metal. and Min. Soc. of South Africa.*) (16) Nov. 28.
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Slimes Process at the Consolidated Mercur Gold Mines.* George Moore. (16) Dec. 5.

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The Hydraulic Plant for Drawing Steel Shells, at the Imperial Arsenal, Osaka, Japan.* Gompei Kuwada. (14) Nov. 28.
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The Electrical Equipment of a Gold Dredge.* Ralph L. Montagu. (42) Oct.
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The Construction of the Great Northern Railway of Canada, 1899-1900.* J. M. Shanly, M. Can. Soc. C. E. (5) Vol. 16, Pt. 1.
Competition of Steam *vs.* Electric Parallels. C. H. Davis, M. Can. Soc. C. E. (5) Vol. 16, Pt. 1.
Concerning Leaky Fireboxes. T. S. Reilly. (61) Oct. 20.
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Some Notes on Acceleration—Electric *v.* Steam. P. Walter d'Alton, M. Inst. C. E., and John Mannheim. (12) Nov. 6.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THEORY OF THE SPHERICAL DOME WITH A HOMOGENEOUS SURFACE, AND OF THE FRAMED DOME; ALSO NOTES ON THE CONSTRUCTION OF MASONRY AND METAL DOMES.

By E. Schmitt, Assoc. M. Am. Soc. C. E.

To be Presented January 6th, 1904.

In this paper the writer presents what he believes to be original information on a subject, regarding which little or nothing has appeared in American engineering literature, as far as he has been able to ascertain. He has endeavored, also, to set out plainly the relations between the principal stresses in domes, and their magnitude; and, further, to acquaint American engineers with a method of framed-dome construction, simple in theory, and rational in execution.

Large domes of this kind exist in this country, presumably in few instances, perhaps in one instance only, at the present time, namely, in the dome of the Library of Congress, at Washington, D. C.*

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* The structural design for this dome, consisting of an outer and an inner shell, was suggested and computed by the writer in 1892, under the direction of Gen. Thomas Lincoln Casey, Corps of Engineers, U. S. A., and of Bernard R. Green, M. Am. Soc. C. E., in immediate charge.

The formulas for the stresses in a homogeneous domical shell, as deduced by Dr. Robison, Schwedler, and Rankine, leave their separate origin and related actions obscure, not only in their deduction, but also for the reason that they are cloaked in the abominable trigonometrical functions.*

Domes of all forms and shapes, constructed in all kinds of material, have been executed in both ancient and modern times. In the case of the older masonry domes, their execution was looked upon by contemporaries as a venturesome undertaking, an experiment inspiring awe and creating a feeling of uncertainty as to their future behavior. Later, praise and admiration were the reward for these bold and courageous designers. Modern designers should feel similarly inclined toward the old masters. The domes they built stand to-day. The Pantheon, the Santa Sophia, the dome at Florence, the dome of St. Peter's: structures, to have a chance to execute which, nowadays, would be considered by any engineer an honor gratifying his professional ambition to a high degree.

There is no doubt that the old masters knew, only in a general way, what they were doing when they built their large domes. This may be surmised from the nature of the reinforcements applied to these structures at one time or another. The nature of the "weak spot" in a dome was not known positively by them.

Some engineers have designed, or are designing, domes on principles similar to those used in the investigation of the cylindrical vault; others treat the ribs (across the diameter) of a framed dome as a three-hinged arch. Both methods are incorrect. Correct principles were worked out some seventy years ago.

While this paper does not attempt to cover all that can be said on the subject of domes, enough will be given to enable a designer to handle a problem with intelligence. In this respect, the writer believes he is the first to suggest a method of arranging the stone coursing of masonry domes so as to do away with the defects experienced in the past, and, perhaps, give a new impetus for the execution of that monumental feature in architectural and engineering design, which has been avoided, not so much because of its cost, but

*The use of these functions in practical working formulas, the writer is bold to say, is an annoyance. If reduced to co-ordination and rectification, the conception of the problem becomes clearer, involving the whole structure, as it were, more as a being with some life than as a mere mathematical expression. A number of examples illustrating this could be presented.

because its stability has been distrusted. This, the writer believes he can overcome with the methods to be proposed.

By stating first some propositions relative to the subject, what follows will be understood more readily.

Theorem.—If, upon a circular ring, there acts a uniform radial pressure, either inwardly or outwardly, then the stress per unit length of circumference, and for a unit length of cross-section of the ring, will be equal to the product of the unit pressure by the number of unit lengths in the radius of curvature of the ring. In Fig. 1 let

R = radius of curvature;

$a = 1$ = unit of length of circumference (for small angles its chord is assumed to have the same magnitude);

H = the unit pressure thereon;

P = the tangential peripheral stress produced thereby.

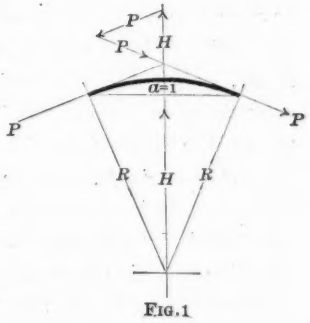


FIG. 1

Then, $P = H R$ ..... (1)

Forming the triangle of forces, as shown at the top of Fig. 1, the following proportion proves the proposition:

$$P : H :: R : a\ (= 1).$$

Surface Properties of a Sphere.—If a sphere has a radius, R, and each square unit of its surface a weight, p, then the weight, W, of any (complete) zone of the sphere, having a height, a, will be:

$$W = 2\ R\ \pi\ a\ p \quad \ldots\ldots (2)$$

If a zone be unity in height, then:

$$W = 2\ R\ \pi\ p \quad \ldots\ldots (3)$$

Considering now a spherical sector, having a base equal to unity at the equator; then a spherical square in the same sector at a parallel, having (at the base of the square) the radius, r, has a weight of:

$$W = \frac{2\ R\ \pi\ p}{2\ R\ \pi}\ \frac{r}{R} = p\ \frac{r}{R} \quad \ldots\ldots (4)$$

If, however, the length of the base of the square, at the elevation, r, be a unit in length, then the weight, W, becomes:

$$W = \frac{2\ R\ \pi\ p}{2\ r\ \pi} = p\ \frac{R}{r} \quad \ldots\ldots (5)$$

When the zone is not a unit in height, but such that its length, in the direction of the meridian, becomes unity, then the weight of the spherical square (see Fig. 2) will be:

$$W = p \frac{R}{r_o} \text{ sin. } i = p \frac{R r_o}{r_o R} = p \ldots\ldots (6)$$

$$\left(\text{in which sin. } i = \frac{r_o}{R}\right)$$

Therefore, the weight of a spherical square, at any parallel having a base and a meridional height equal to a unit measure, will be

$$W = p \ldots\ldots\ldots\ldots (6)$$

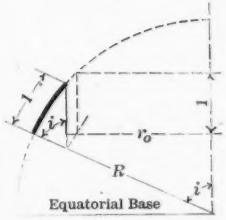


FIG. 2

The main subject will be divided, purposely, into four cases, shown and explained in Figs. 3, 4, 5 and 6. Cases I and II are the fundamental ones. By combining the effective stresses in these, the other two are solved. It will then be seen that, at any point in a complete sphere, three forces are active, and thus the place can be found where the weak part in masonry domes exists.

Case I.—Determine the stress in the crown ring. This stress, it can be inferred, is always a compressive one.

Case II.—Determine, at the base of the dome, the tangential, meridional thrust, always acting downward as a compressive stress. Determine, also, for the same place, the circumferential ring stress, *B*. This, at the bed-joint of a dome, is always tension.

Case III.—Combine Cases I and II, and the stresses at any point in a full hemispherical dome can be obtained.

Case IV.—By combining Cases I and II properly, the stresses in the crown and base rings can be found, and also those at any intermediate point between the two, in a truncated dome.

MAGNITUDE OF THE STRESSES.

Case I.—The stress per unit length of meridian, and per unit length of circumference, of the crown ring is found by forming the triangle of forces, with p as the known quantity, as by Equation 6, and as shown in Fig. 3, comparing this with the similar triangle, composed of the dimensions of the sphere, as R, r_o and h_o, gives the proportion:

$$p : H_o :: r_o : h_o$$

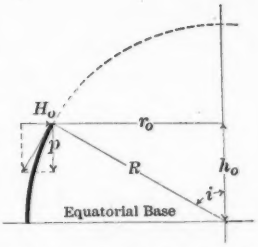
or,

$$H_o r_o = p h_o \ldots\ldots\ldots\ldots (7)$$

By the proposition and Equation 1, the ring stress, P, in the crown ring is, therefore:

$$P = p\, h_o \ldots\ldots\ldots\ldots (8)$$

In this equation, h_o is, in each instance, the elevation of the crown ring above the (under circumstances imaginary) equatorial base of the dome.

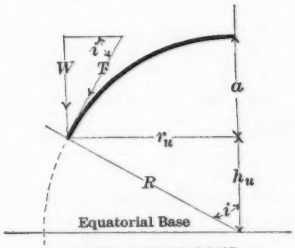


Case I—OPEN OR TRUNCATED DOME
Opening at Elevation h_o above the Equatorial Base

FIG. 3

No other force but this exists around the top of an open dome, except when a superimposed load, as that of a balustrade or a lantern, is placed on top of the crown ring, which arrangement is adopted in most of the more modern domes.

Case II.—At the base of any dome, two principal stresses exist, and must balance each other: The tangential meridional thrust, T, and the horizontal ring stress, B, in the bed-joint of the base, and which would burst the shell open if not taken care of by the tensile strength of the material of which the dome is constructed, or by some auxiliary means therein, as a metal ring or hoop. Both stresses are naturally due to the weight, W, of the dome. With this weight (see Equation 2), the triangle of forces, W, T and i, is formed (as shown in Fig. 4), and compared with the triangle of dimensions, r_u, h_u, R. Now form the proportion:



Case II—CLOSED DOME
Base at Elevation h_u above the Equator

FIG. 4.

$$W : T :: r_u : R,$$

whence

$$T = W \frac{R}{r_u} \ldots\ldots\ldots\ldots\ldots (9)^*$$

Substituting for W its value, gives:

$$T = \frac{R}{r_u}\, 2\, R\, \pi\, a\, p \ldots\ldots\ldots\ldots\ldots (10)$$

If B, the resisting or balancing force, as it were, is assumed to be reckoned per unit length of circumference, and for one unit length along the meridian, then, for equilibrium around the entire base of the dome:

$$T = 2\, r_u\, \pi\, B \ldots\ldots\ldots\ldots\ldots (11)$$

* This formula is applicable, whatever may be the shape of the dome.

and with reference to the value of T, just found:

$$\frac{R}{r_u} 2\,R\,\pi\,a\,p = 2\,r_u\,\pi\,B$$

from which,

$$B = \frac{R}{r^2{}_u}\,a\,p \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

The value, T, thus far, has been considered as the sum total of the meridional tangential thrusts all around the base of the dome; if it be also reckoned per unit length of the circumference of the base, and designated by A, then

$$A = \frac{T}{2\,r_u\,\pi}$$

and, with reference to the value of T,

$$A = \frac{R^2}{r^2{}_u}\,a\,p \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Thus it is seen that the ring stress, B, at any point around the circumference of the base of a dome, is of the same magnitude, or intensity, per unit length, as the tangential meridional thrust, A, for the same circumferential length; they are opposite in character, however, A being always a compressive, and B always a tensile stress.

Assuming the minus sign to indicate tension, and the plus sign compression, A and B can be expressed by making first the following substitutions in Equations 12 and 13:

$a = R - h$, and $r^2{}_u = R^2 - h^2{}_u = (R - h_u)\,(R + h_u)$, by:

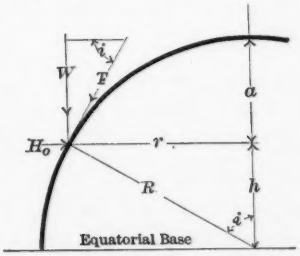
$$A = + \frac{R^2}{R + h_u}\,p, \qquad B = - \frac{R^2}{R + h_u}\,p \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Case III.—If it be assumed that the closed dome of Case II be such that when placed on top of the open dome of Case I, they, together, form a complete half sphere, or a full dome (Fig. 5), the stresses at any parallel, or latitude, having a radius, r, and an elevation, h, above the equatorial base, will be (adding Equations 8 and 14):

$$A = + \frac{R^2}{R + h}\,p,$$

and

$$B = - \frac{R^2}{R + h}\,p + p\,h \ldots . (15)$$



Case III.—FULL DOME, OR HALF SPHERE.
FIG. 5

Special values of A and B are:

At the crown, or the pole, where $h = R$,

$A = +\frac{1}{2} R\,p$, compression; $B = +\frac{1}{2} R\,p$, also compression. (16)

At the base, or equator, where $h = 0$,

$A = +R\,p$, compression; $B = -R\,p$, now tension... (17)

Equation 15, for the ring stress, B, shows it to be composed of a negative and a positive term, due to the upper and lower part of the dome, respectively, and in reference to the parallel in question. Observing also, as just shown, that B passes from compression at the pole, to tension at the equator, it can be concluded that there exists a point, or a special value of B, where B becomes zero, or, in other words, where the two terms become equal. Therefore, putting

$$B = 0, \text{ or } 0 = -\frac{R^2}{R+h}p + p\,h$$

and solving for h, it is found that

$$h = \frac{R}{2} \pm \sqrt{R^2 + \left(\frac{R}{2}\right)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

and for $R = 1$, $h = \frac{1}{2} \pm \sqrt{\frac{5}{4}} = 0.618\,R$ ..... (19)

For the angle from the vertex, for which B becomes zero,

$$\text{cos. } i = \frac{h}{R} = 0.618, \text{ and } i = 51^\circ\,49' \ldots\ldots\ldots\ldots (20)$$

This point, at which $B = 0$, is called the principal joint of rupture. It can therefore be said: The parallel at an elevation of 0.618 R above the equatorial base divides the surface of a full dome into two parts, such that all parts above it are in compression in all directions, while the lower part is in compression and in tension. The meridional stress is a compressive thrust, the ring stress a tensile one, beginning with nothing at the joint of rupture until at the base it reaches the maximum value of $B = -p\,R$.

This fact of a tensile ring stress existing in all courses below the joint of rupture, has made the (brick) masonry dome a failure, and it will continue to be a failure unless the coursings (of stone) are designed so that they can transmit tension. On the other hand, it is to be emphasized that any masonry dome extending from the pole no further than to the point of rupture is as safe and stable as any other construction designed to cover a space, as for instance a roof truss or a floor, provided there be placed around the base a ring or hoop

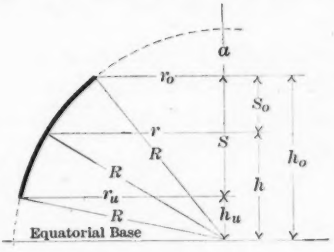
sufficiently strong to take up a tensile stress, B, or provided the base course be designed to take such a stress.

Case IV.—The Truncated Dome.—By combining properly the formulas already established, the following two general expressions for A and B, for any intermediate point, as for the parallel, r (Fig. 6), can be derived:

$$A = + \frac{R^2}{r^2} S_o p,$$

$$B = - \frac{R^2}{r^2} S_o p + p h \ldots (21)$$

Regarding the last term in the equation for B, it is to be remembered here, as in future cases, that it expresses the compressive ring stress in reference to that part of the sphere which is below the parallel in question, as by Equation 8. Therefore, when h reaches the lower limit $= h_u$, p becomes zero in that term.



Case IV.—OPEN DOME

Opening at Elevation h_o above the Equator,
Base at Elevation h_u above the Equator,

FIG. 6

The special values of A and B are:

At crown ring,

$$A_o = 0, \qquad B_o = p h_o \ldots\ldots\ldots\ldots\ldots (22)$$

At base,

$$A_u = + \frac{R^2}{r_u^2} S p, \quad B = - \frac{R^2}{r_u^2} S p \ldots\ldots\ldots (23)$$

In domes, open at the top, special joints of rupture exist, and occur at points below the principal joint of rupture, provided the base of such truncated domes be also below that joint. This will appear in Figs. 16 and 19, wherein the principal stresses have been constructed graphically for several cases of domes.

Case V.—For this case, where it is assumed that an additional load q, is imposed upon the crown ring per linear unit of its circumference, the equations for the principal stresses will also be given. Considering that a crown-ring load, Q, as it is transmitted from the top downward becomes distributed over larger and larger circles, the portion of the weight, q, at a parallel having a radius, r, will only be (Fig. 7):

$$q \frac{r_o}{r}, \text{ wherein } q = \frac{Q}{2 r_o \pi} \ldots\ldots\ldots\ldots\ldots (24)$$

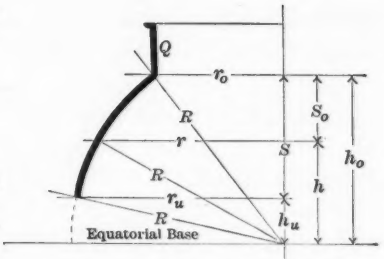
Referring to the general term for the meridional thrust,

$$A = W\frac{R}{r}$$

W becomes, in this instance,

$$W = q\frac{r_o}{r} + \frac{R}{r}S_o p \ldots (25)$$

and, in this general case of a truncated dome with a lantern load, the stresses, at any parallel, as r, will be:



Case V.—OPEN TRUNCATED DOME WITH A LANTERN OF WEIGHT Q

FIG. 7

$$A = +q\frac{R\,r_o}{r^2} + \frac{R^2}{r^2}S_o p \ldots\ldots (26)$$

$$B = \pm q\frac{R\,r_o}{r^2} - \frac{R^2}{r^2}S_o p + p_u h \ldots\ldots (27)$$

Special values:

At the crown, for $r = r_o$, $S_o = 0$, $h = h_o$, and the upper sign for B, whence,

$$A = +q\frac{R}{r_o}, \qquad B_o = +(p+q)\,h_o \ldots\ldots (28)^*$$

$$B = +q\frac{R}{r_o} + p\,h_o \ldots\ldots (28a)^*$$

At the bottom, at an elevation, h_u, above the equatorial base, $r = r_u$, $S_o = S$, $p_u = 0$, for $h = h_u$, therefore:

$$A = +q\frac{R\,r_o}{r^2{}_u} + \frac{R^2}{r^2{}_u}Sp \ldots\ldots (29)$$

$$B = -q\frac{R\,r_o}{r^2{}_u} - \frac{R^2}{r^2{}_u}S\,p \ldots\ldots (30)$$

This concludes the theory of the stresses in a homogeneous spherical shell of uniform thickness, to be extended somewhat, however, in what follows. The writer is not acquainted with any treatment of this problem considering other stresses than those determined in this paper.

In passing now to the theory of the framed, or open-paneled, dome, invented and executed by W. Schwedler in 1866, it was seen that the spherical shape of the homogeneous dome surface was maintained by the ring stresses, B, counteracting, by means of the tensile strength of the material of the shell, the bursting and splitting action of the meridional thrust, A.

*While Equation 28 holds good for the cross-section of the crown ring, Equation 28a holds good for a point immediately below the same, being a circumferential shear in the bed-joint of the crown ring.

It suggested itself to Schwedler, therefore, that, if he desired to construct a dome with meridional ribs, it was proper to arrange horizontal rings, so as to tie the ribs together by hoops, as it were.

Schwedler's dome can be well likened to a masonry dome, the panels taking the places of the voussoirs; but, unlike the masonry dome, there are no open joints or interruptions in the main parts making up the construction, all stresses being transmitted by structural members connected continuously at all panel points, and designed to resist whatever kind of stresses may come upon them. Although masonry domes, being also stable structures above the joint of rupture, and in the sense that the stones then have to resist compression only, as mentioned before, the lower courses, those below the joint of rupture, are not so situated, even if the base course should be reinforced by a hoop of proper strength, the tendency of the courses in the tension zone to split open, along the meridians, would still exist.

ONE FORM OF A SCHWEDLER DOME

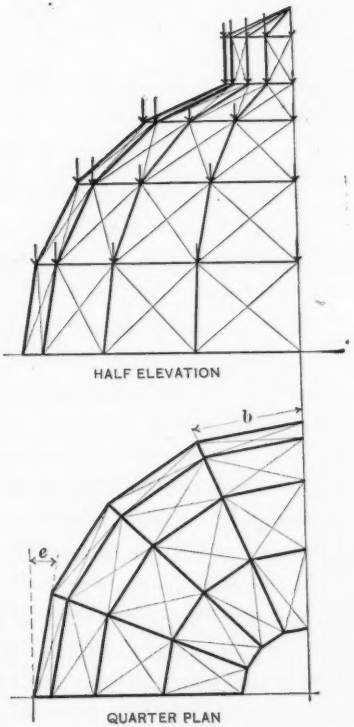


FIG. 8

In Fig. 8 one form of a Schwedler dome has been represented. From the nature of its conception, it is evident that it may be given almost any shape; the principle of its calculation once understood, there will be no difficulty in working out any special form of dome.

The spacing of the ribs and rings, generally speaking, is an arbitrary matter. When it is considered, however, that they are intended to be executed in the form of polygons, or at least to be designed in such a manner as to reduce to a minimum the compound stresses occurring in them if they are curved, and, further, that the rings have

the function of preventing a change in the form of the ribs, certain limits in the direction of the spacing of the ribs and rings cannot be exceeded. The data in Table No. 1, taken from existing examples, will give some information on this question of precedent:

TABLE No. 1.

Diameter, in feet.	Number of radial ribs.	Rise.	Number of panels.	Diameter of crown ring, in feet.	Designer.
80.....	16	1 : 8	3	Closed Dome.	Schwedler.
100.....	24	1 : 8	4	20	"
140.....	24	1 : 8	4	20	"
104.....	32	1 : 2	6	23	Library of Congress.
124.....	20†	1 : 2	7	15	Becker.

† With two jack-ribs in each main sector.

In the framed dome, as in other framed structures, the loads are assumed to be concentrated at the panel points. The determination of these loads, as indicated in Fig. 8, needs no further explanation.

As regards the stresses: The ribs are always in compression, the crown ring, also, always in compression, the foot ring always in tension. As to the intermediate ring-stresses, it is not so certain. Generally speaking, it might be said that, within an angle of 51° 49′ from the vertex, they are in compression, while below this angle they might presumably be in tension. On the other hand, it can be shown in advance how the loads must be distributed so as to increase or decrease any possible tension or compression in a ring.

In Fig. 8, conceive the topmost zone removed, then the crown ring of the lower remaining part will be in compression, and the more so the more that ring is loaded. The lower ring of the zone removed, however, if this zone be considered by itself, will be in tension, and the more so the more the topmost ring is loaded. Reasoning in a like manner for any of the rings, and the loads that might happen to come on the ring zones above them, the following laws, governing the ring and rib stresses, can be formulated:

1.—The top and bottom rings are stressed most under maximum loading.

2.—Likewise the ribs.

3.—In the intermediate rings, the greatest compression, if any, will take place when the ring itself is heavily, and all rings above it, lightly, loaded.

4.—For the greatest tension therein, if any, the reverse loading holds good.

5.—In reference to any ring, loads on zones below it do not affect the stresses in any member of the dome located above the ring in question.

6.—Any zone, from the top downward, may be removed, without disturbing the integrity of the remaining part of the dome.

7.—Inversely, the dome may be conceived to be built by placing zone upon zone, until it is completed.

Under the guidance of these rules, the following set of formulas, drawn up in reference to the diagram of a Schwedler dome shown in Fig. 9, need but little further explanation.

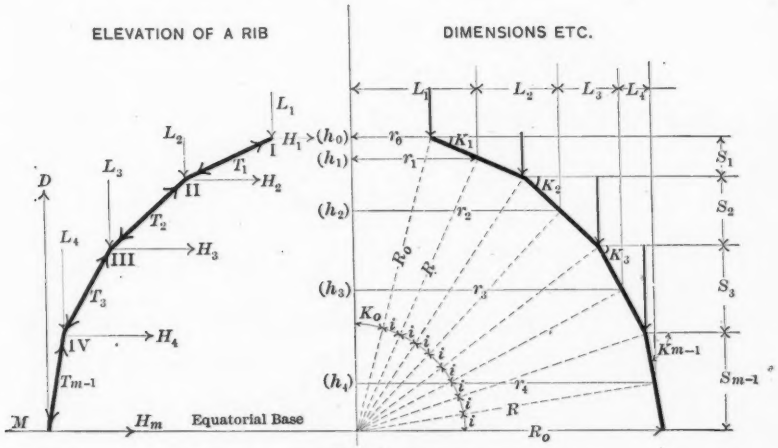


FIG. 9

Radii and elevations.		Angles and functions.	
$r_0 = R_0 \cos.(8\,i)$	$h_0 = R_0 \sin.(8\,i)$	$i = \frac{90° - K_0}{2\,(m-1)}$	$\sin. K_0 = \frac{r_0}{R_0}$
$r_1 = R \cos.(7\,i)$	$h_1 = R \sin.(7\,i)$	$K_1 = (K + i)$	$\sin. K_m = \frac{r_m}{R}$
$r_2 = R \cos.(5\,i)$	$h_3 = R \sin.(5\,i)$	$K_2 = (K + 3\,i)$	
$r_3 = R \cos.(3\,i)$	$h_4 = R \sin.(3\,i)$	$K_3 = (K + 5\,i)$	$\cos. K_m = \frac{hm}{R}$
$r_m = R \cos.(1\,i)$	$h_{m-1} = R \sin.(1\,i)$	$K_{m-1} = [K + (2\,m - 3)\,i]$	

In Fig. 9 some of the dimensions (h and r) refer to the middle of the panel lengths of the main ribs, except h_o and r_o. For practical purposes, scale h and r, etc.

The ribs have each $(M-1)$ equal panels; $M = 5$ in this example.

Circumscribed radius $= R_o$.

Inscribed radius $= R_o \cos. i = R$.

Analytic Method.

Stresses in the Ribs.

Panel Point I.—In Fig. 10, the forces, L_1, the two ring forces, P_1, and the thrust in the rafter, T_1, must balance. Resolving for vertical direction:

$$L_1 - T_1 \sin. K_1 = 0$$

in which, $\sin. K_1 = \frac{r_1}{R}$

$$T_1 = + L_1 \frac{R}{r_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

Panel Point II.—Similarly:

$$L_2 + T_1 \sin. K_1 - T_2 \sin. K_2 = 0$$

in which, $\sin. K_2 = \frac{r_2}{R}$

$$T_2 = + (L_1 + L_2) \frac{R}{r_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (32)$$

Panel Point III.

$$T_3 = + (L_1 + L_2 + L_3) \frac{R}{r_3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (33)$$

Generally:

$$T_{m-1} = +$$

$$(L_1 + L_2 + \ldots\ldots L_{m-1}) \frac{R}{r_{m-1}} \ldots (34)$$

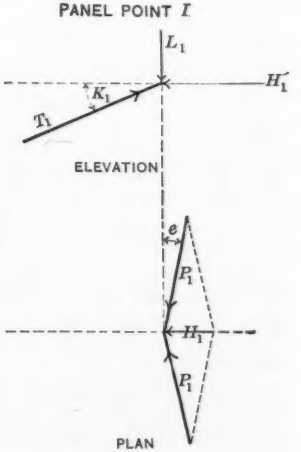


FIG. 10

Stresses in the Rings Under Dead Load.

Panel Point I.—Resolving for horizontal direction, and considering that H_1 is the resultant of the two ring forces, P_1, gives for equilibrium, Fig. 10, and with the value for T_1 above:

$$- H_1 + T_1 \cos. K_1 = 0$$

in which, $\cos. K_1 = \frac{h_1}{R}$

However (see Fig. 10, plan, and Fig. 12, plan of foot ring), since

$$H_1 = 2\,P_1 \text{ sin. } e, \text{ and } e = \frac{360°}{2\,N} = \frac{180°}{N},$$

it is found that

$$P_1 = + \frac{1}{2 \text{ sin. } e} L_1 \text{ cotan. } K_1$$

$$\text{in which, cotan. } K_1 = \frac{h^1}{r_1}, \quad \text{and} \quad \text{sin. } e = \frac{b}{2\,R_o}$$

$$P_1 = + L_1 \frac{h_1\,R}{r_1\,b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (35)$$

Panel Point II.—In Fig. 11, with reference to the values, T, Equations 31 to 34,

$$H_2 - T_1 \text{ cos. } K_1 + T \text{ cos. } K_2 = 0,$$

$$\text{but sin. } e = \frac{b}{2\,R_o}, \text{ cos. } K_2 = \frac{h_2}{R} \text{ and } \text{ cotan. } K_2 = \frac{h_2}{r_2}$$

$$P_2 = \frac{1}{2 \text{ sin. } e}\left[(L_1 + L_2) \text{ cotan. } K_2 - L_1 \text{ cotan. } K_1 \right]$$

$$= \frac{R_o}{b}\left[(L_1 + L_2)\frac{h_2}{r_2} - L_1 \frac{h_1}{r_1} \right] \ldots\ldots\ldots\ldots (36)$$

Panel Point III.—Etc.

$$P_3 = \frac{R_o}{b}\left[(L_1 + L_2 + L_3)\frac{h_3}{r_3} - (L_1 + L_2)\frac{h_2}{r_2} \right] \ldots\ldots\ldots (37)$$

Foot Ring.—See Fig. 13.

$$P_m = - \frac{R_o}{b}\left[(L_1 + L_2 + L_3 + \ldots + L_{m-1})\frac{h_{m-1}}{r_{m-1}} \right] \ldots (38)$$

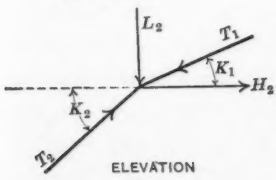


FIG. 11

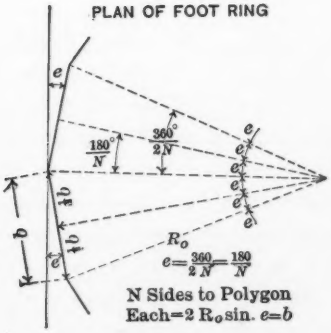


FIG. 12.

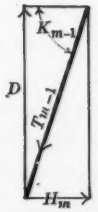


FIG. 13

GRAPHIC METHOD.

. Dead Load.

Referring to Fig. 14, upper part, lay off from *O* to *IV*, the loads L_1, L_2, L_3, L_4, . . . , and form the force polygons for each panel point, as *I*, *II*, *III*, . . . , *M*, as follows:

Panel Point I.

Known: $L_1 = O\,I$, Unknown: T_1 and H_1,

Polygon: $O\ I\ a\ O$, now $T_1 = I\,a$, compression, $H_1 = a\ O$ (←)

Panel Point II.

Known: $L_2 = I\,II$, and $T_1 = Ia$, Unknown: T_2 and H_2,

Polygon: $a\ I\ II\ a$, now $T_2 = II\,b$, compression, $H_2 = b\ a$ (→)

Panel Point III.

Known: $L_3 = II\,III$, and $T_2 = IIb$ Unknown: T_3 and H_3,

Polygon: $b\ II\ III\ b$, now $T_3 = III\,c$, compression, $H_3 = c\ b$ (→)

Likewise: $T_4 = IV\,d$, compression, $H_4 = d\,c$ (→)

Panel Point V. (*M*).

Known: $D = L_1 + L_2 + L_3 + L_4$, and T_4 Unknown: H_m,

Polygon: $O\ IV\ d\ O$, now $H_m = O\,d$ (→)

The ring stresses can now be found by resolving them from their respective resultants, H_1, H_2, H_3, H_4, H_m, as shown in the upper part of Fig. 14.

The exact nature of the stresses is determined by knowing that the crown ring is always in compression, and that this is indicated by the plus sign. In the graphic method, it should be remembered that any force acting toward a panel point indicates compression, while the opposite action indicates tension. Further, that, in the triangle of forces, the resolvents have their arrows, indicating the sense of the force, running in the opposite direction to the arrow of the resultant. Proper care is to be taken to transpose these arrows from the force polygon to the respective members of the framework and *vice versa*. Thus, in the example, it is found that all the rings, except the crown ring, are in tension.

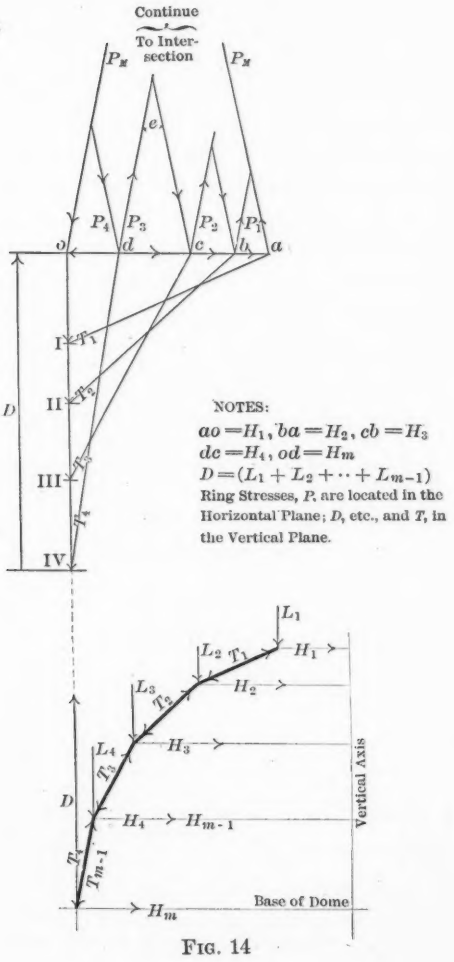


FIG. 14

Live Loads.

Let Q_1, Q_2, Q_3, Q_4, etc., designate the combined vertical components of the wind- and snow- loads on the respective panel points, then the maximum-compression, and maximum-tension stresses, which may possibly take place in the rings, due to these loads, will be as shown in Table No. 2.

TABLE No. 2.

	Maximum compression stress.	Maximum tension stress.	
Crown Ring.	$P_1 = Q_1 \frac{\text{cotan. } K_1}{2 \text{ sin. } e}$ $P_1 = + Q_1 \frac{h_1}{r_1} \frac{R_o}{b}$	$P_1 = - 0$	(39)
Ring II.....	$P_2 = + Q_2 \frac{\text{cotan. } K_2}{2 \text{ sin. } e}$ $P_2 = + Q_2 \frac{h_2}{r_2} \frac{R_o}{b}$	$P_2 = - \frac{Q_1}{2 \text{ sin. } e}$ (cotan. K_1 — cotan. K_2) $= - Q_1 \frac{R_o}{b} \left(\frac{h_1}{r_1} - \frac{h_2}{r_2} \right)$	(40)*
Ring III....	$P_3 = + Q_3 \frac{h_3}{r_3} \frac{R_o}{b}$	$P_3 = - \frac{(Q_1 + Q_2)}{2 \text{ sin. } e}$ (cotan. K_2 — cotan. K_3) = $- (Q_1 + Q_2) \frac{R_o}{b} \left(\frac{h_2}{r_2} - \frac{h_3}{r_3} \right)$	(41)
Ring IV....	$P_4 = + Q_4 \frac{h_4}{r_4} \frac{R_o}{b}$	$P_4 = - (Q_1 + Q_2 + Q_3) \frac{R_o}{b} \left(\frac{h_3}{r_3} - \frac{h_4}{r_4} \right)$	(42)
Foot Ring .	$P_5 = 0$	$P_m = - (Q_1 + Q_2 + \dots + Q_{m-1}) \frac{R_o}{b} \frac{h_{m-1}}{r_{m-1}}$	(43)

* Compare Equations 36, etc.

These results must be combined with the stresses found previously for the dead load.

For the rib stresses and the top and bottom rings, no separate formulas are needed, as a maximum load affects them most. It will be best to include the live loads at once with the loads, "L," in both the analytic and graphic determination of the stresses in these members.

Diagonals have been shown in all the panels of Fig. 8. For the dead load, none are required. For the effect of the live load, Schwedler proposed the following approximate solution:

Of two adjacent ribs, consider one only to be loaded with the loads, Q_1, Q_2, etc. Determine the rib stresses for each panel, and, for the several panels, assume this to be the shearing force acting on one of the diagonals. The other diagonal will take up a like amount of tensile stress.

Let d_1, d_2, d_3 . . . ., be the angles formed by the diagonals with the rib-panel members, and D_1, D_2, D_3, . . . etc., the stresses in the diagonals; then, if F be the length of a rib panel, and l the length of a diagonal, approximately, cos. $d_1 = \frac{F_1}{l_1}$, cos. $d_2 = \frac{F_2}{l_2}$, etc., and

$$D_1 = -\frac{Q_1}{\text{sin. } K_1 \text{ cos. } d_1}, \text{ or } D_1 = -Q_1 \frac{R\, l_1}{r_1 F_1} \quad \ldots\ldots\ldots\ldots\ldots (44)^*$$

$$D_2 = -\frac{Q_1 + Q_2}{\text{sin. } K_2 \text{ cos. } d_2}, \text{ or } D_2 = -(Q_1 + Q_2) \frac{R\, l_2}{r_2 F_2} \quad \ldots\ldots\ldots (45)^*$$

Similarly,

$$D_3 = -(Q_1 + Q_2 + Q_3) \frac{R}{r_3} \frac{l_3}{F_3}, \text{ etc.} \quad \ldots\ldots\ldots (46)^*$$

By the graphic method, the diagonal stresses are found by developing a dome sector with its panels. With the known rib-panel stresses, $\Sigma\, Q_m \frac{R}{r_m}$, triangles of force can be formed for each panel point.

The fundamental formulas derived for the spherical dome with a homogeneous shell of uniform thickness hold good for domes of any other shape and of variable thickness, provided the proper substitution of the values for p and W be made therein.

In this it should be remembered that, in the expression, $p\,h$, p signifies the weight per square

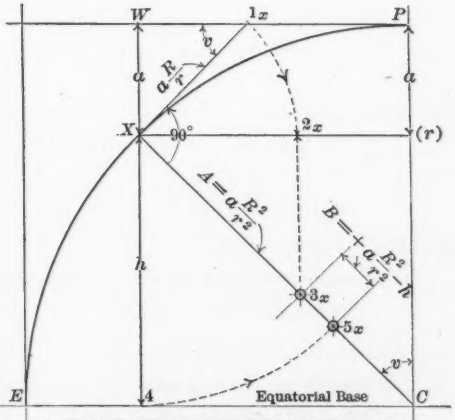


DIAGRAM SHOWING METHOD OF DETERMINING THE MAGNITUDE OF THE PRINCIPAL STRESSES FOR ANY POINT, X, OF A FULL DOME.

FIG. 15

*Derived, partly, by substituting in Equations 31 to 34, Q for L.

unit of shell, and for that part of it, only, which is located just below a particular parallel of latitude; whereas W represents the weight of the dome sector above that parallel. W, therefore, is not related to the now variable weight, p, in the same manner as it is in the case of the spherical dome of uniform thickness.

Concerning the Schwedler dome, those desiring more information are referred to existing literature, wherein the framed dome is treated as a statical indetermined structure, and wherein inclined loads are also considered. The writer believes that Schwedler's static method, as given in this paper, is accurate enough for all practical purposes.

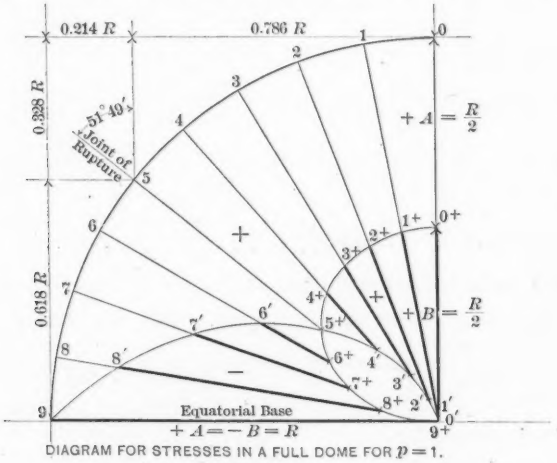


DIAGRAM FOR STRESSES IN A FULL DOME FOR $p = 1$.

FIG. 16

For instance:

A_7 = Line 7 to 7^+, A_2 = Line 2 to 2^+

B_7 = Line 7^1 to 7^+, B_2 = Line 2^1 to 2^+

A_5 = Line 5 to 5^{+1}, $B_5 = 5^{+1} = 0$.

Below the Joint of Rupture:

Measure the A stresses over the extent of the light and heavy radi-ordinates.

Above the Joint of Rupture:

Measure the A stresses over the extent of the light lines only.

The B stresses are shown by the heavy lines.

Above the Joint of Rupture, B is compression.

Below the Joint of Rupture, B is tension.

Setting down again the expressions for the principal stresses for a spherical dome of uniform thickness as:

In general:

$$A = + W \frac{R}{r}, \qquad B = - W \frac{R}{r} + p\,h \ldots\ldots\ldots (47)$$

Spherical dome:

$$A = + \frac{R^2}{r^2}\, a\,p, \qquad B = - \frac{R^2}{r^2}\, a\,p + p\,h \ldots\ldots\ldots (48)$$

They can be readily produced graphically, as shown in Figs. 15 to 19. The initial quantity used in the construction of all the diagrams is:

$$W = R\,a\,p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (49)$$

namely the weight of a zone-sector having a height equal to a, and a base equal to a unit of length at the equator.

This weight, W, is represented, for $p = 1$, in

Fig. 15, by the line, $W\,X = a$,

Fig. 17, " " " $W\,X' = a$,

Fig. 17, " " " $w\,X' = S$, for the zone S_o.

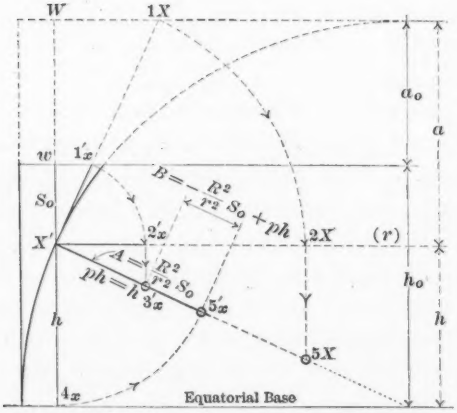


DIAGRAM SHOWING CONSTRUCTION OF THE MAGNITUDE OF THE A AND B STRESSES IN A TRUNCATED DOME FOR ANY POINT, X', ALSO FOR A FULL DOME AT THE SAME LATITUDE, FOR $p = 1$.

FIG. 17

In a truncated dome, $A = X'\,3'\,x$, $p\,h = X'\,5'\,x$, $B = 3'\,x\,5'\,x$.

In a full dome $A = X'\,5\,X$, $p\,h = X'\,5'\,X$, $B = 5'\,x\,5\,X$.

$$x'\,1'\,x = S_o \frac{R}{r}, \quad x'\,1\,X = a \frac{R}{r}.$$

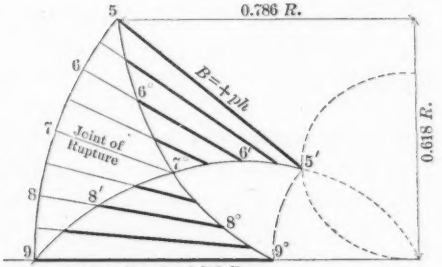
See Equations 2, 3, 4 and 5.

The construction is as follows:

Full Dome. Fig. 15.—For any point, X, and the radi-ordinate, CX, draw $W4$, produce XI_x at right angles to CX. Bring down, with X as a center, 1_x to 2_x, then vertically down to 3_x. Bring up to the same radius CX, with X as a center, the height, h, whence the stresses, A and B, have been laid off on the radi-ordinate, CX, as noted in the diagram.

Truncated Domes.—Proceed similarly.

Repeating this construction for a number of radi-ordinates, the diagrams, Figs. 16, 18 and 19 are obtained.



$+A=-B=ph=0.618\ R.$

MAGNITUDE OF THE STRESSES IN A TRUNCATED DOME, THE HEIGHT OF WHICH HAS BEEN CHOSEN ARBITRARILY, AT 0.618 R, THAT IS, UP TO THE LEVEL OF THE PRINCIPAL JOINT OF RUPTURE OF A FULL DOME. SEE REMARKS RELATING TO FIG. 16.

B STRESSES ABOVE JOINT OF RUPTURE = COMPRESSION.
B STRESSES BELOW JOINT OF RUPTURE = TENSION.

FIG. 18

Examining Figs. 18 and 19, representing cases of truncated domes, it will be noticed that, as in the full dome, two zones exist, as regards the stresses, B; that is, there exists a special joint of rupture, above which B is compression, and below which B is tension, provided the base of the dome is at an elevation less than $0.618\ R$ above the equatorial base.

Entering now upon the question of how to design stone-masonry coursing that it may withstand tension, without regard to the frictional tenacity in the bed and the tensile strength of the mortar in the vertical joints, the writer will be guided by the well-recognized law that, in all important stone construction of a high character, no other material than stone should be used to connect the parts of the structure.

With this point in view, three methods of constructing the stone courses in the tension zones of masonry domes are suggested, as shown in Figs. 20 to 25.

The demands to be fulfilled by the different parts of each stone are as follows:

Each circumferential unit length of bed must be able to withstand a thrust, A.

The least cross-section must be able to withstand a tension, B.

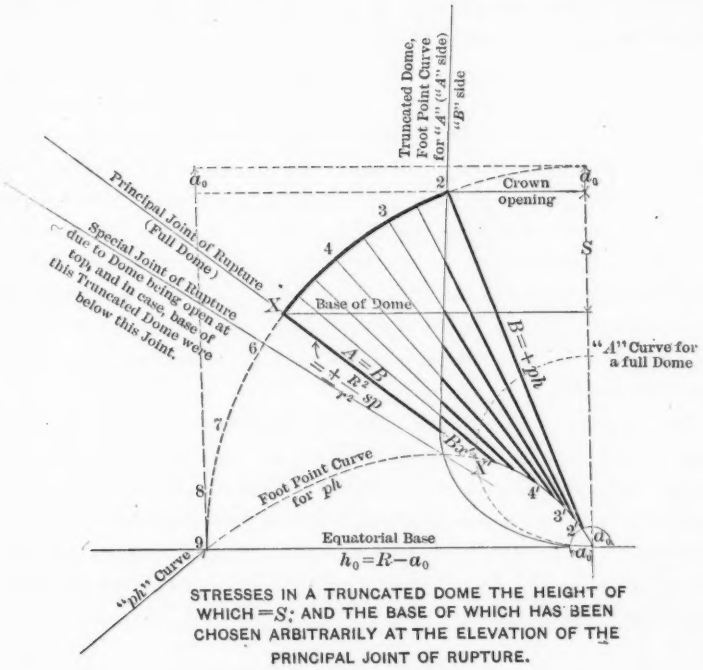


FIG. 19

In Fig. 19 note the large increase in the B stresses, in comparison with those occurring in a closed dome; also the corresponding reduction in the magnitude of the A stresses. The special point of rupture is determined by that radi-ordinate which passes through the intersection of the $p\,h$ and A curves.

A stresses are in light lines (except at the base).

B stresses are in heavy lines.

All stresses are compressive, except the B stress at the base, which is tension.

Note that, immediately below the base of the dome, p becomes zero, and that the stress represented by the line, $B\,x'$, is the compressive stress per unit length of meridian immediately above the bed-joint of the base.

If there be n stones in a course, or $2\,n$ tenons, each must be able to take up at its root a shear $= \dfrac{2\,r\,\pi\,B}{2\,n} = \dfrac{\pi}{n}\ (-\,W\,R + p\,h\,r)$.....(50)

Each tenon must also be able to take up, on the depth of its radial face, a like amount of compression.

Considering that, at the base of a dome, A and B have the same magnitude, and that the tensile strength of stones is much less than their compressive strength, it would seem to be sufficient to proportion the bottom course in all its parts for the stress, B; then all the other tension courses will be amply strong if similarly constructed. It may be, however, a great point in economy to lessen the depth of the tenons, from course to course, according to the decrease that takes place in the stress, B, from the base up to the joint of rupture. It is evident that, up to this joint, a stone of high tensile strength, and above this joint, a lighter material, of high compressive strength, should be used.

The lengths of the stones must be aliquot parts of the circumference. Use the radial thickness (bed) of the courses as the unit measure. Make the rise of the courses equal to the bed, and make the length of the stones as nearly as possible four times the rise.

For domes of variable thickness, a direct solution is not practical. The problem must be solved by successive trials, and for each parallel, if economy be an object.

Possibilities in Stone-Masonry Dome Construction.

Let it be required to find what diameter a half spherical dome of uniform thickness might have, if built with stones having :

Bed and rise = 1 ft.;

Weight = 164 lbs. per cubic foot;

Safe tensile strength
= 150 lbs. per square inch = 18 000 lbs. per square foot;

Safe compressive strength
= 1 200 lbs. per square inch = 144 000 lbs. per square foot.

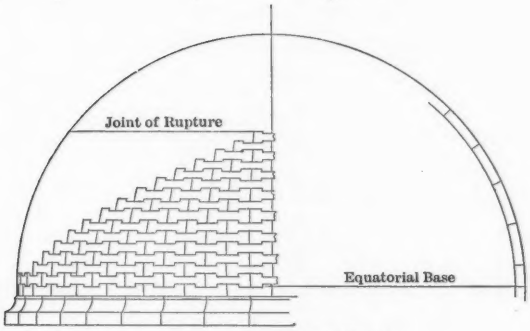
With regard to the latter stress, and Equation 17,

$$R = \frac{A}{p},$$

substitute, for A, 144 000 lbs., and, for p, 164 lbs., and find $R = 875$ ft., or diameter $= 2\,R = 1\,750$ ft.

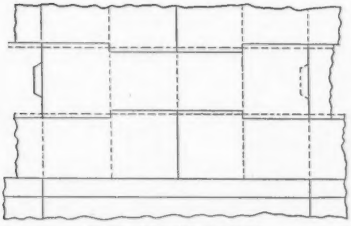
With regard to the tensile strength of the stone, however, and Equation 17

$$R = \frac{B}{p},$$



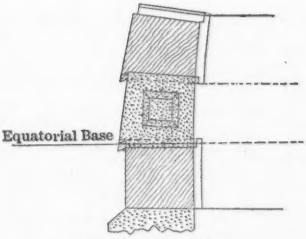
PART ELEVATION OF A DOME
DESIGNED WITH TENSION COURSES.

FIG. 20



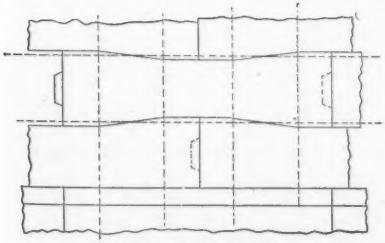
SHOULDERED COURSES.

FIG. 21



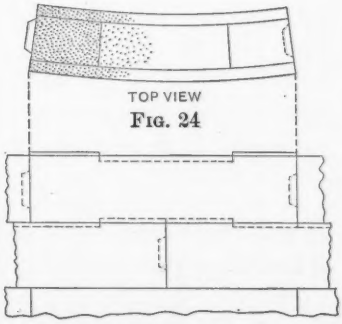
VERTICAL SECTION

FIG. 23



BEVELED STRETCHERS

FIG. 22



TOP VIEW

FIG. 24

CONCEALED BED AND BUILD TENONS

FIG. 25

wherein $B = 18\,000$ lbs., and p, again, $= 164$ lbs., it is found that $R = 110$ ft., say, or the diameter of the sphere $= 2\,R = 220$ ft., only.

Making the stones in the bottom course approximately 4 ft. long, the number of stones in each tension course would be:

(here for the base course) $n = \dfrac{2\,R\,\pi}{4} = \dfrac{R\,\pi}{2}$,

Each stone having two tenons, their number will be $= 2\,n$, or $= R\,\pi$.

For the compressive stress on the radial face of each tenon:

$$\frac{2\,R\,\pi\,B}{R\,\pi} = 2\,B,$$

now, the length of the tenons being 12 ins., and the safe permissible stress thereon $= 1\,200$ lbs. per square inch, their depth will be:

$$\frac{2 \times 18\,000}{12 \times 1\,200} = 2\tfrac{1}{2} \text{ ins.}$$

Reversing the example, it might be asked, what must be the characteristic properties of a stone, so that a dome of a certain diameter may be built therewith?

Let t = the thickness of the stone, in feet = unit of measure;

g = its specific gravity;

then $p = t^3 \times g \times 62$.

Let k = the tensile strength per square foot;

then $B = p\,R = t^2\,k$.

Substituting herein, for p, its value, and expressing the radius of the dome in terms of its thickness,

as: $$R = N\,t, \text{ or } N = \frac{R}{t},$$

then $$\frac{R}{t} = N = \frac{t\,k}{t^3\,g \times 62}.$$

Since $t =$ unit (of measure) (see remark just made above), this term reduces to the general formula:

$$N = \frac{k}{g \times 62} \qquad \text{.....(51)}$$

Substituting herein, per example, for $k = 18\,000$ lbs. per square foot, and for the specific gravity of the stone, $g = 2.75$,

$$N = \frac{18\,000}{2.75 \times 62} = 110, \text{ say,}$$

or, in other words: If a stone has the stated characteristics, a dome constructed therewith may have any radius which does not exceed 110 times the thickness of the stone.

TABLE No. 3.

Name.	Place.	Material.	Interior diameter.	Shape.	Thickness.		Date when built.	Name of builder.	*N*, say.
					At base.	At top.			
Dome of the Pantheon.	Rome.	Brick.	142 ft. Opening at the top, 28½ ft. in diameter.	Half sphere. Single shell.	7½ ft. Buttress, 21 ft., including base.	4 ft.	A. D. 25.	Marcus Agrippa (Roman).	10.
Santa Sophia.	Constantinople.	Brick below. Tufa above. (?)	115 ft. Closed at the top.	Half sphere. Single shell. Resting on a stone base.	2¾ ft. Over buttresses, 8 ft.	2 ft.	A. D. 532 to 537.	Anthemius of Thales, and Isidorus of Milet (both Greeks).	21.
Santa Maria del Fiore.	Florence.	Brick.	139 ft. Opening at the top, 20 ft. in diameter.	Egg-form. Eight-sided. Double shell, with lantern.	Inner shell: 7 ft. Outer shell: 2¾ ft. Base, 15 ft. thick.	7 ft. 2½ ft.	A. D. 1421 to 1434.	Brunelleschi (Italian)	11 and 28.
St. Peter's.	Rome.	Rubble and brick, on stone base.	139 ft. Opening at the top, 25 ft. in diameter.	Egg-shape. Circular in plan. Double shell,* with lantern.	Inner shell: 6 ft. Outer shell: 3 ft. Base, 10 ft. thick.	6 ft. 3 ft.	A. D. 1513 to 1563.	Michael Angelo (Italian).	14 and 28.

* Both shells are traversed by ribs connecting them along meridians from bottom to top.

Inversely: The thickness of a dome, under the given conditions, ought to be equal to the $\frac{1}{110}$ part of its radius.

For example: With the above stone, a dome 660 ft. in diameter should have a thickness of

$$t = \frac{330}{110} = 3 \text{ ft.}$$

Much more could be said on the subject, but the writer will conclude by giving, in Table No. 3, the approximate dimensions of the four large domes mentioned in the beginning, and, in Table No. 4, the properties of some of the principal kinds of stone, which material the writer believes is the proper one to use, at least in the tension zones of masonry domes.

TABLE No. 4.—AVERAGE WEIGHTS AND STRENGTHS OF BUILDING STONES, ETC., FROM VARIOUS SOURCES; ALSO THE VALUES OF THE RATIO OF RADIUS TO THICKNESS, *N*, WHEN USED IN DOMICAL STRUCTURES OF UNIFORM THICKNESS.

Material.	Weight, in pounds per cubic foot.	Ultimate Strength, per Square Inch.					*N*, for six times safety.
		Compression.	Tension.		Shearing.	Rupture.	
			Ultimate.	Elastic limit.			
Granite	173	12 000	1 500	1 125	4 300	1 800	210
Marble	168	8 000	1 000	750	2 900	1 200	142
Limestone	151	7 200	900	675	2 600	1 100	144
Sandstone	154	9 600	1 200	900	3 400	1 440	187
Bluestone	160	11 000	1 375	1 050	4 000	2 300	210
Brickwork in lime mortar	112	1 000	50	.....	.....	.....	10
Brickwork in cement mortar	120	2 000	300	225	450	500	60
Concrete	150	1 500	425	320	600	500	68
Terra cotta	.....	5 000	(?)	.....	(?)	1 500	.....
Terra cotta work	.....	2 000	.....	.....	.....	.....	.....
Aluminum	166	.....	.....	6 500	.....	.....	960
Steel	489	.....	.....	.....	48 000	.....	2 400

STRESSES USED BY THE REINFORCED CONCRETE CONSTRUCTION COMPANIES.

	Safe.	Safe.	Safe.		Ultimate.		
Special rock concrete	150	2 400	200	.....	690	.....	192

In contemplating the construction of a stone masonry dome, the material to be used ought to be tested as to its strength. Table No. 4 is submitted for general information only.

With the exception of the dome of the Pantheon, the construction of the other three domes is wrong in constructive design.

In the Santa Sophia, forty openings are arranged around the base; and in the case of the last two structures the "Rib Principle" is a main feature. Both these arrangements are out of place in the tension zone of a spherical brick-masonry dome.

While no defects exist in the dome of the Pantheon, the other domes have shown fissures and cracks, presumably all below the joint of rupture, and have had to be reinforced, at least in the case of St. Peter's, a number of times.

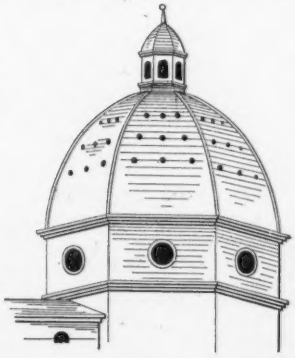
Theory of the Homogeneous Pyramoidal Dome, Containing All Other Forms as Special Cases.

In the first part of this paper only the spherical form of domes was considered. It can be shown, however, by making proper substitutions in the formulas of stresses for the pyramoidal dome to be derived, that the spherical, conoidal, conical, in fact, all forms of domes are special cases of this general case.

The ground plan of a pyramoidal dome, as implied by the geometrical name, may be any regular polygon.

Horizontal sections through this dome are all similar figures. The roof has usually a convex surface toward the outside. One of the two prime axial sections may be assumed to govern the design of the outline, which may be a circle, a circular arc, an ellipse, a parabola, etc. The use of a regular curve for the roof will enable the designer to produce and compute the various dimensions and weights of any or of the whole part of the surface with more ease than if the curve is an arbitrary one.

Fig. 26 gives an idea of the appearance of a pyramoidal dome. The "Duomo" of Florence, in Italy, is a representative example of this kind of dome, and is mentioned in the first part of this paper.



PYRAMOIDAL DOME.
Fig. 26

The theory of the stresses is based upon the following propositions:

I.—Any parallel of altitude (circumferential joint) divides the dome into an upper and a lower part.

II.—Each side of the polygonal bottom course (of the upper part) is assumed to act as a circumferential and connected tie.

III.—Each side of the polygonal top course (of the lower part) is assumed to be subjected to simple compression only.

IV.—The corners of all the polygonal horizontal courses are assumed to be (pin-) connected joints.

V.—The tensional circumferential stress in the bottom course of the upper part balances, by the tenacity of the homogeneous material of which the shell is constructed (and must therefore be equal to), the meridional downward, pressing and bursting thrust, due to the weight of the dome.

VI.—The tensional stress, mentioned under *V* is reduced, and may, at a particular altitude, be totally balanced, by the compressive stress existing in the top course of the lower part, and in case the separation, under *I*, ceases.

VII.—The weight of the dome, as it is transmitted downward from course to course, is assumed to be distributed uniformly around the circumference, at any altitude.

VIII.—No other (external) forces than its own weight act upon the dome.

In Fig. 27, let

H_o = the sum of the forces acting upon each side of a polygonal course at any altitude;

P = the radial resultant of the H_o forces, acting through the rib corners;

B = the tensional or compressional ring stress created in any course, in turn, by the radial forces, P.

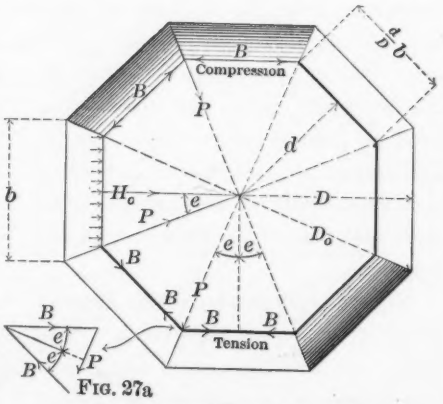


FIG. 27a

Number of Sides of Base $=N$

Circumference " " $=Nb$

$$\sin. e = \frac{b}{2D_o}$$

FIG. 27

Then, with reference to the dimensions and angles noted at the left side of the figure:

$$P = 2 \times \frac{1}{2} \frac{H_o}{\cos.\ e} = H_o \frac{D_o}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (52)$$

Forming (Fig. 27*a*) the triangle of forces, $B\ P\ B$, for any of the corners, gives:

$$2\ B \sin.\ e = P, \text{ or } B = \frac{P}{2 \sin.\ e} = P \frac{D_o}{b} \quad \ldots\ldots\ldots\ldots (53)$$

and, substituting for P the value of Equation 52, finally,

$$B = H_o \frac{D_o}{D\ 2 \sin.\ e} = H_o \frac{D_o^2}{D\ b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (54)$$

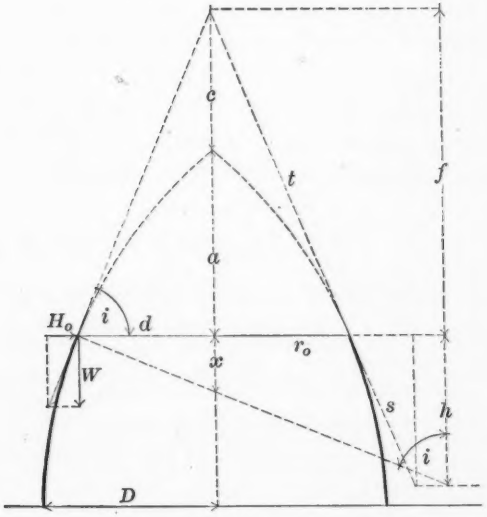


FIG. 28

In Fig. 28, D = Inscribed radius;

D_o = Circumscribed radius;

b = Length of each of the N sides at the base;

d = Inscribed radius at any parallel of altitude;

$x : d :: h : r_o$, $x = \dfrac{d\,h}{r_o}$, $a + c = f$;

$x : d :: d : f$, $x = \dfrac{d^2}{f}$;

R = Radius of curvature at altitude, d;

$R^2 = r_o^2 + h^2$, $s : h :: t : (a + c) = f$.

For the magnitude of the compressive force at the top course of the lower part, in Fig. 28:

Let W = the weight of each side of the top course, the rise of which, along the surface of the dome, being equal to unity;

R = the radius of curvature of the dome surface along the meridian and for the unit length thereof, from the top edge of the same course downward;

h = the vertical distance of the evolute point of R below the top course;

D = the short diameter, at the base of the dome;

d = " " " " " top of the dome;

H_o = the horizontal inward thrust for each side of the top course, created by the weight, W, of the same course.

Then, by forming the triangle of forces with H_o and W, and comparing the same with the similar triangle formed by the dimensions of the dome, R, r_o, and h, the result is the proportion:

$$H_o : W = h : r_o,$$

or,
$$H_o = W\frac{h}{r_o}, \text{ or } H_o = W\frac{x}{d} \ldots\ldots\ldots (55)$$

The forces at the base of an upper part of the dome, say, for instance, at an elevation, d, are found, with reference to Proposition V, and Fig. 29, as follows:

Let W = the total weight of the dome above the parallel, d;

A = the resulting tangential meridional thrust;

R = the radius of curvature of the dome surface at the same altitude.

Then, by similar triangles:

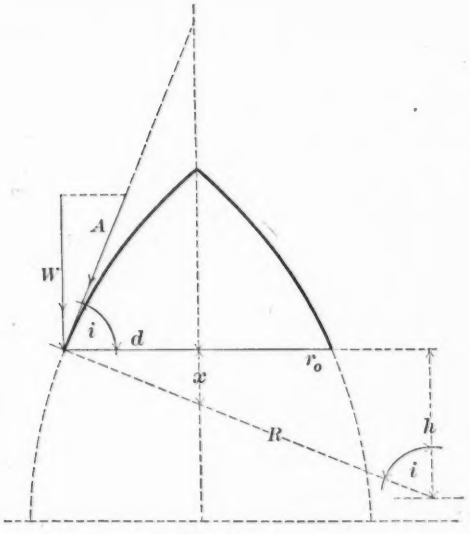
$$A : W :: R : r_o, \text{ or } :: s : h,$$

whence
$$A = + W\frac{R}{r_o} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (56)$$

and also
$$A = + W\frac{s}{h} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (57)$$

For equilibrium around the polygonal base, the sum total of the circumferential tensile stresses, B, must be equal in amount to A, but opposite in character, and will therefore be:

$$B = - W\frac{R}{r_o}, \text{ or } B = - W\frac{S}{h} \ldots\ldots\ldots\ldots\ldots (58)$$



$A : W :: R : r_o$

$A = W \frac{R}{r_o}$

FIG. 29

Formulas 55 to 58 give the gross amount of the magnitude of the several stresses in their most general form, and for the gross weights of the dome shell.

In the following formulas the stresses will all be reduced to "per unit length," and "per unit of cross-section" of the shell of the dome.

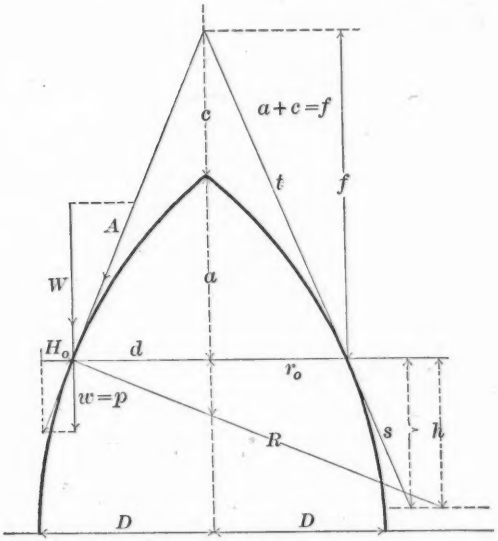
Referring, further, all dimensions and weights at any altitude to the dimensions and weights of the base course, gives the following relations (see Figs. 27 and 30):

Compressive Ring Stress in the Top Course of the Lower Part.—Let $p\,b$ = the weight of one side of the main base course,

$$\text{then } W = p\,b\,\frac{d}{D}$$

which equals the weight of one side of a polygonal course at the altitude, d. Substituting this value for W in Equation 55:

$$H_o = p\,b\,\frac{d\,h}{D\,r_o} \qquad (59)$$



$w : H_o :: r_o : h :: d : x :: f : d.$
$W : A :: r_o : R :: f : t :: h : s.$
$r_o = R \sin. i, \qquad x = \frac{dh}{r_o} = \frac{d^2}{F}$

FIG. 30

this, in Equation (52), gives:

$$P = p\,b\,\frac{d\,h}{r_o}\,\frac{D_o}{D^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (60)$$

and, finally, this value in Equation 53, the compressive stress per unit length at the top of an open dome will be:

$$B = + p\,\frac{d\,h}{r_o}\,\frac{D_o^2}{D^2}, \text{ or } B = + p\,x\,\frac{D_o^2}{D^2} \ldots\ldots\ldots\ldots \quad (61)$$

For the two principal stresses at the base of any dome, we had:

$$A = + W\frac{R}{r_o}, \text{ and } B = - W\frac{R}{r_o} \ldots\ldots\ldots\ldots \quad (62)$$

Let $N\,b$ = circumference of the base course, then

$N\,b\,\frac{d}{D}$ = the circumference of the dome at any altitude, as d, and for the unit length of circumference:

$$A = + W\frac{R\,D}{r_o\,N\,b\,d}, \quad B = - W\frac{R\,D}{r_o\,N\,b\,d} \ldots\ldots\ldots\ldots \quad (63)$$

By uniting the upper and lower parts of the dome again, having been conceived until now separated, under Proposition I, and com-

bining the equations derived for the stresses under that condition, the actual stresses existing at any point in the surface of a pyramoidal dome are found.

Combining, therefore, Equations 61 and 63, with reference to Fig. 30, the magnitude of the tangential meridional thrust, A, per unit of length of circumference, is found to be:

$$A = + W \frac{R\,D}{r_o\,N\,b\,d}, \text{ or, also, } A = + W \frac{s\,D}{h\,N\,b\,d} \ldots\ldots\ldots (64)$$

For the shearing stress along the surface of the bed-joint of a course, and per unit of length of the same, and for the tensile stress in the radial cross-section of the same course, having a rise equal to a unit of length of meridian:

$$B = - W \frac{R\,D}{r_o\,N\,b\,d} + p \frac{d\,h}{r_o} \frac{D_o^2}{D^2} \ldots\ldots\ldots\ldots\ldots (65)$$

$$\text{or, also, } B = - W \frac{s\,D}{h\,N\,b\,d} + p\,x \frac{D_o^2}{D^2} \ldots\ldots\ldots\ldots\ldots (66)$$

These, then, are the general equations containing the theory of the principal stresses in domes of a pyramoidal shape.

To make good the statement that other forms of domes are only special cases of this form of dome, and for the reason that such specialization is the purpose of applied mechanics, the formulas for the stresses in spherical, conical, and conoidal-shaped domes will now be found.

The Spherical Dome.

The several kinds of this dome have already been treated in the first part of this paper, and, therefore, attention will be confined to the production of the formulas for the stresses in a full or hemispherical dome only.

Referring to Figs. 27 and 30, and Equations 64 and 65, the following substitutions will be made:

$N\,b = 2\,R\,\pi$, circumference of the dome at base;

$D_o = D = R$, radius of the hemisphere;

$d = r_o$, radius of any parallel of altitude;

$h = R - a$, vertical distance between the evolute point of R and the joint in question (*i. e.*, center of sphere);

$W = 2\,R\,\pi\,a\,p$, weight of the whole spherical segment of the dome, above the same.

Then, after reducing:

$$A = + \frac{R^2}{r_o^2} a p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (67)$$

$$B = - \frac{R^2}{r_o^2} a p + p h \ldots\ldots\ldots\ldots\ldots\ldots (68)$$

Considering that $a = R - h$, $r_o^2 = R^2 - h^2 = (R + h)(R - h)$,

then, also, $A = + \frac{R^2}{R + h} p$, and $B = - \frac{R^2}{R + h} + p h \ldots\ldots\ldots\ldots (69)$

These results are the same as given by Equations 14 and 15, in the first part of this paper. The conclusions arrived at there need not be repeated again.

The Conical Dome.

Referring to Equations 64 and 66, and Figs. 27, 30 and 31, and conceiving the necessary modifications to be made, to transform Fig. 30 into a conical dome, as shown in Fig. 31, we have first:

$c = 0$, $f = a$, $D_o = D$, $t = S$, $r_o = d = r$, $h = x$, and, as in Fig. 31,

$$x = \frac{r^2}{a}.$$

Recalling now, for a moment, the algebraic expression for the envelope of a cone, we have, further:

$W = r \pi S p$, total weight of the conical surface;

$W = \frac{r \pi S p}{2 r \pi}$ = the weight of a cone sector thereof, with a base = unit of length $= \frac{S}{2} p$.

This result is obtained, also, by reducing the expressions in Equation 63:

$$W \frac{D}{N b d} = \frac{W}{N b \frac{d}{D}} = \frac{r \pi S p}{2 r \pi} = \frac{S}{2} p.$$

Conforming now the expressions for A and B, to the quantities just found, they become:

$$A = + \frac{S^2}{2 a} p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (70)$$

$$B = - \frac{S^2}{2 a} p_o + \frac{r^2}{a} p_u \ldots\ldots\ldots\ldots\ldots\ldots (71)$$

The magnitude of the two terms in the equation for B will determine, when evaluated, whether there is tension or compression in a

course. In its present shape, not much can be learned from the formula in this respect; but by the substitution,

$$S^2 = a^2 + r^2, \text{ and } p_o = p_u = p,$$

it can be brought to the form:

$$B = -p\left(\frac{a^2 - r^2}{2a}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (72)$$

Interpreting this formula, the following statements can be made:

If a equals r, then the cone has a slope of 45°, B becomes zero, that is, none of the courses is in tension; each simply transmits, from course to course downward, the thrust, A.

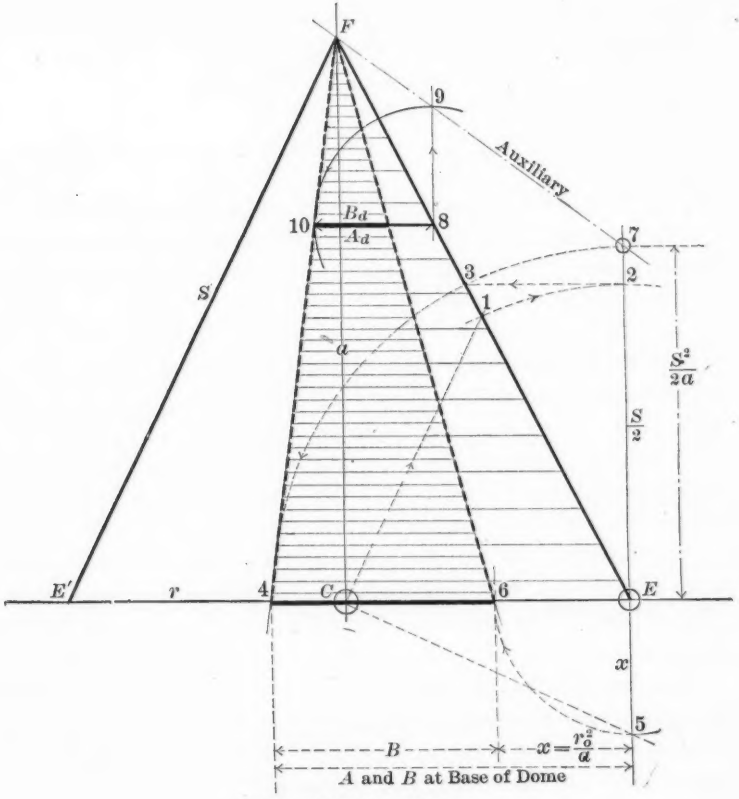
If, now, a be greater than r, the inclination of the sides of the cone to the horizon is more than 45°, and B will have the negative, or tension sign. All courses, therefore, from the top down, in a complete cone, sustain tension (and compression due to A).

If the inclination be less than 45°, the courses are subjected to compression in the direction of the parallels of altitude, as well as in the direction of the sloping sides of the cone.

For the determination of the tensional stress at the bottom of the main base course, this formula is not applicable, and, instead, the original form of the formula, Equation 71 must be used for this purpose.

Remembering that the first term therein relates to the effect of the upper part, and the second term to the effect of the lower part, of the dome, in reference to a particular altitude, it will be seen that at the base of any dome the second term vanishes.

A and B become there equal in amount, but are opposite in character.



HIGH CONICAL DOME.

FIG. 31

In Fig. 31, E'-$C = C$-$E = r$;

C-1 $\parallel$ E'-F, C-1 $= 1$-$E = \frac{1}{2}$ E-$F = \frac{S}{2}$;

2-$E = \frac{S}{2}$, 2-3 $\parallel$ E'-E;

3-E : 2-E : : S : a, 3-$E = \frac{S^2}{2a}$;

C-5 $\perp$ C-1 $=$ $\perp$ E'-F; $x : r = r : a$, $x = \frac{r^2}{a}$;

$A = \frac{S^2}{2a}$, $B = -\frac{S^2}{2a} + x$, $p = 1$ (unit).

4-$E = A$, 4-6 $= B$, 6-$E = x = \frac{r^2}{a}$,

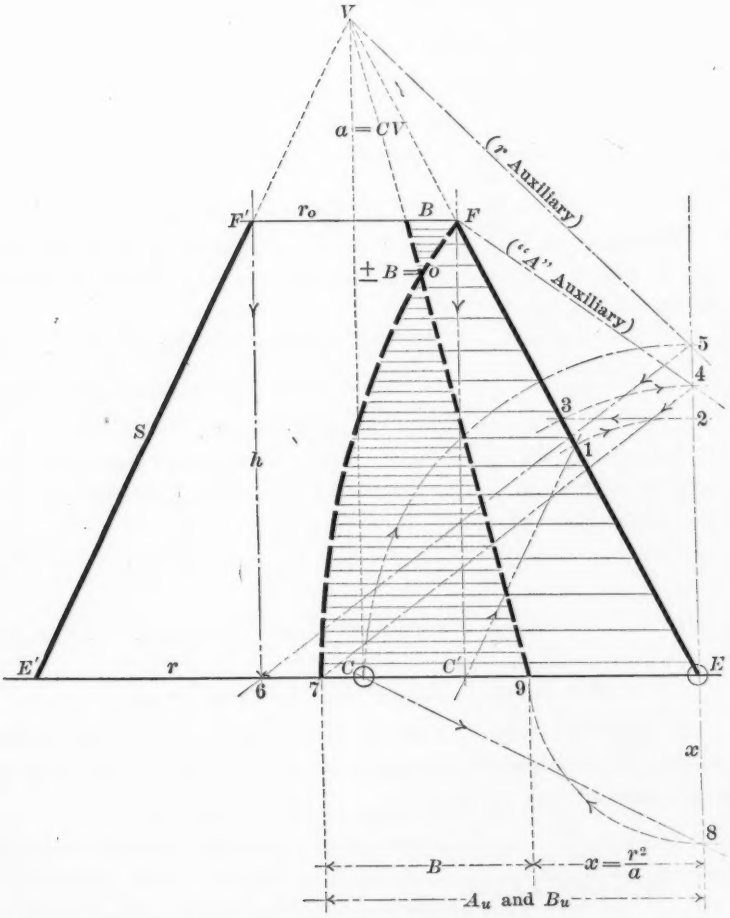
E-F = Base line for the stresses A,

6-F = " " " " " B,

4-F = Terminal line for both A and B; however, any other point of this line can be constructed by the use of the auxiliary line 7-F;

$$7\text{-}E = \frac{S^2}{2\,a} = 3\text{-}E.$$

For Point, 8, for instance, form the circuit 8-9-10.



TRUNCATED OR LOW CONICAL DOME.

FIG. 32

In Fig. 32, h = height of frustum;

S = length of side;

r_o = radius at top;

r = radius at any joint below top;

C'-1 $\parallel$ E'-F', I-$E = \frac{1}{2} S$, 2-3 $\parallel$ E'-E, 3-$E = \frac{S^2}{2\,h}$;

5-E = C-E = r, 6-C = r_o, 6-E = $r_o + r$, draw 5-6,

then, 4-7 $\parallel$ 5-6, now E-7 $= \frac{S^2}{2\,h} \times \frac{r + r_o}{r} = A$, C-8 $\perp$ E^1-F^1;

9-E = 8-E = $x = \frac{r^2}{a}$, 7-9 = $B = -\frac{S^2}{2\,h} \times \frac{r + r_o}{r} + \frac{r^2}{a}$;

E-F = base line for A;

9-V = base line for B;

Curve 7-F = terminal line for A and B.

The Truncated or Low Conical Dome.

Referring to Fig. 32, and the above-mentioned general formulas for A and B, we have, for the stresses per unit length of circumference at any parallel, first:

$W = S\,\pi\,p\,(r_o + r)$, the weight of the envelope from r to r_o, and

$W = \frac{S}{2} \frac{r_o + r}{r}\,p$, the weight of a cone sector thereof with a base = unity, at the parallel of altitude, r.

Introducing this latter value, in the formulas, and assuming for a moment that the line E' - E, be an intermediate point between the actual base of the dome and its top:

$$A = +\,p\,\frac{S^2}{2\,h}\,\frac{r_o + r}{r} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (73)$$

$$B = -\,p\,\frac{S^2}{2\,h}\,\frac{r_o + r}{r} + \frac{r^2}{a}\,p \qquad \ldots\ldots\ldots\ldots\ldots\ldots (74)$$

The Truncated Dome with a Lantern Load.

To obtain the stresses, A and B, in this case, we have to add to the weight, W, in the above formulas, the effect of the lantern load, Q, at the parallel, r, in question.

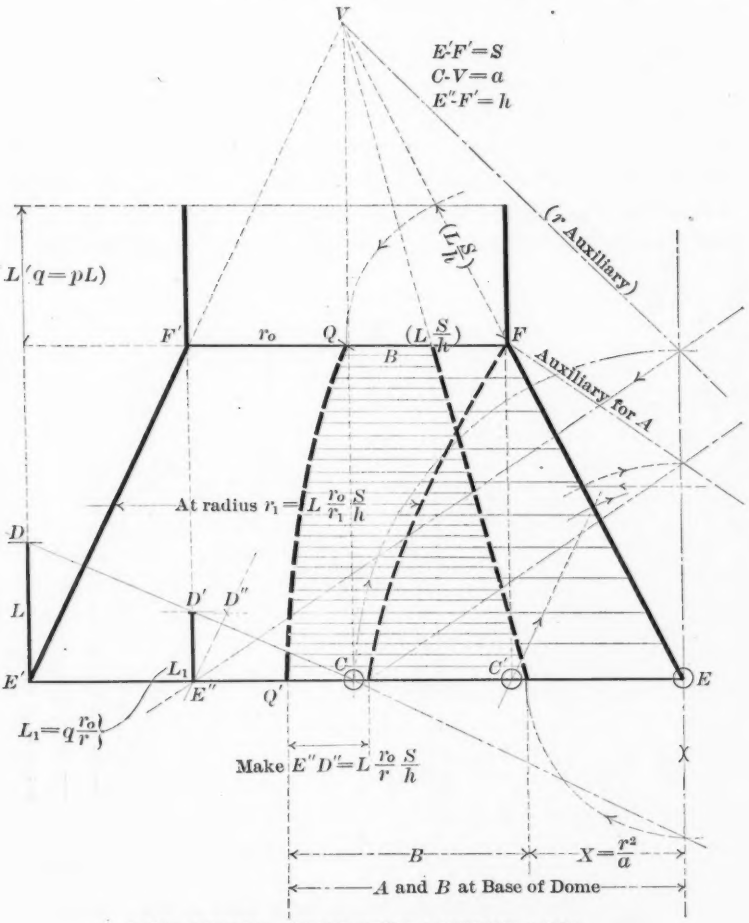
If $q = \frac{Q}{2\,r_o\,\pi}$, the load per unit of circumference at the top, then

$Q = q\,2\,r_o\,\pi\,p$, and

$W = q_r = \frac{Q}{2\,r\,\pi} = q\,\frac{r_o}{r}$, the load per unit of circumference at the parallel, r. Now:

$$A = + q \frac{r_o}{r} \frac{S}{h} + p \frac{S^2}{2h} \frac{r_o + r}{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (75)$$

$$B = - q \frac{r_o}{r} \frac{S}{h} - p \frac{S^2}{2h} \frac{r_o + r}{r} + \frac{r^2}{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots (76)$$



LOW CONICAL DOME WITH LANTERN LOAD.

FIG. 33

In Fig. 33, L = height of superimposed load, assumed to have a weight = p per square unit; then weight on top = $p \times L$.

Make E'-$D = L$, draw D-C, E''-$C = r_o$, E''-$D'' \parallel E'$-F''; then, as noted for the lower joint, E''-$D'' = p\, L \frac{r_o}{r} \frac{S}{h} = Q'\, C$.

Now find:

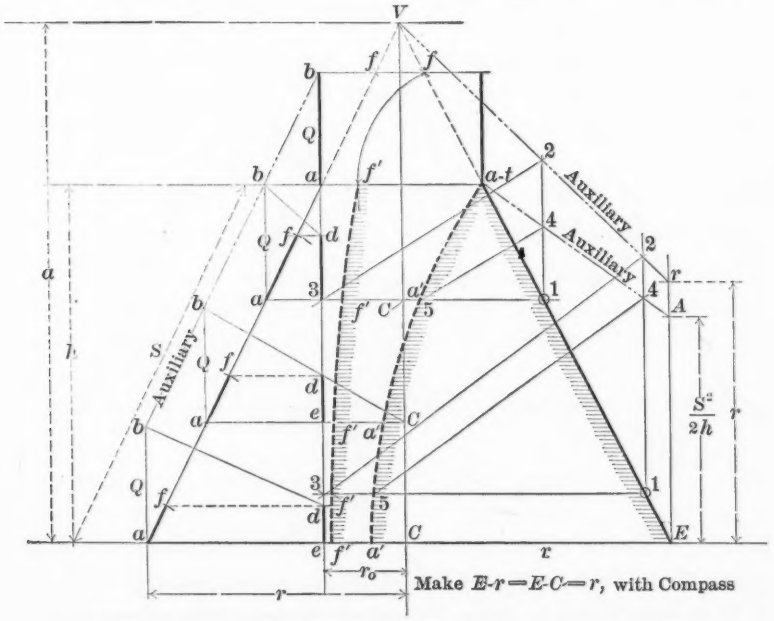
$$A = + p\,L\,\frac{r_o}{r}\,\frac{S}{h} + p\,\frac{S^2}{2\,h}\,\frac{r + r_o}{r} \text{ (see Fig. 32),}$$

$$B = - p\,L\,\frac{r_o}{r}\,\frac{S}{h} - p\,\frac{S^2}{2\,h}\,\frac{r + r_o}{r} + p\,\frac{r^2}{a}\,.$$

Stresses are laid off for p = unit.

For further explanations see Figs. 31 and 32.

All the expressions for the stresses, A and B, as given above, can be readily constructed, as shown, and fully explained, in Figs. 31, 32, and 33. Some of the lines therein are designated as "auxiliaries." Examining Fig. 34, the manner in which these auxiliary lines assist and simplify the construction of the stresses will become manifest.



CONSTRUCTION OF THE STRESS "A," IN A LOW DOME WITH A LANTERN LOAD, Q, AND FOR A WEIGHT = p, PER SQUARE UNIT OF SURFACE.

FIG. 34

In Fig. 34, construct $E\text{-}A = \frac{S^2}{2\,h}$, as previously shown, and $E\text{-}r = r$. Draw the auxiliary lines, $A\text{-}a\text{-}t$ and $r\text{-}V$; and $b\text{-}b\text{-}b$ . . . for Q.

FORMS OF STABLE CIRCULAR DOMES OF MASONRY.

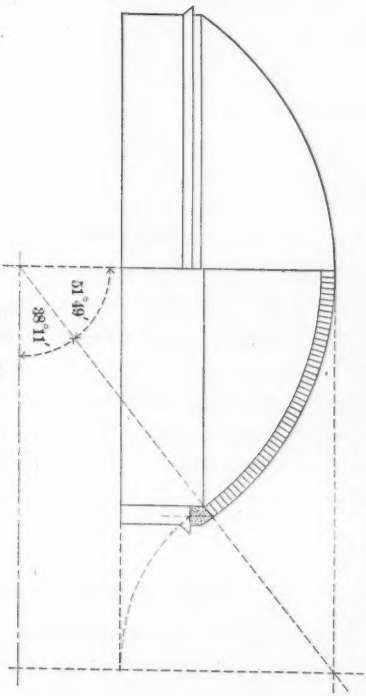


FIG. 35

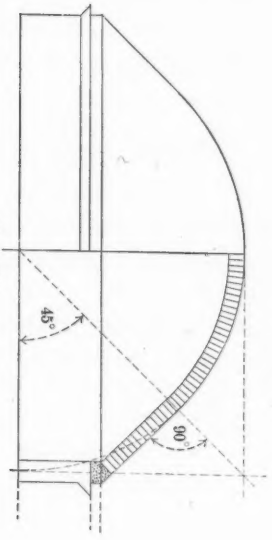


FIG. 36

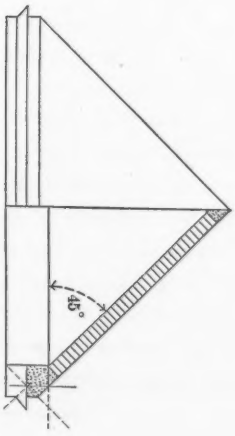


FIG. 37

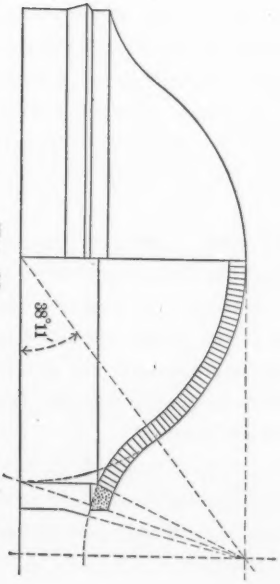


FIG. 38

For any point, as 1, form the circuits, 1-2-3-1, and 1-4-5-1, 4-5 ‖ 3-2; then 1-5 = A, for the cone only.

Form, also, the circuits a-b-C, e-d-f-a; make a'-f' = a-f; a-f = the stress, A, for $Q = q\,\frac{r_o}{r}\,\frac{S}{h}$, and 1-$f'$ = A, total.

Line a-t-E = base line, f'-f' . . . = terminal line for the A stresses.

Conoidal or Pointed Domes.

The conoidal domes resemble the pyramoidal domes in their axial sections; they are, however, circular in plan.

If W be the weight of the dome above a particular parallel of altitude, and 2 d π the circumference of that circle, then the stresses per circumferential linear unit become (Fig. 30):

$$A = + \frac{W}{2\,d\,\pi}\,\frac{R}{r_o} \qquad (77)$$

$$B = - \frac{W}{2\,d\,\pi}\,\frac{R}{r_o} + p\,\frac{d\,h}{r_o} \qquad (78)$$

Joints of Rupture in Conical Domes.*

Examining the four diagrams showing graphically the magnitude of the three prime forces acting at an intermediate point of the shell, one located between the top and the base of a conical dome, it will be noticed that in a full dome, as Fig. 31, no joint of rupture exists. The ring stresses will be either tension, zero, or compression, from top to bottom, according to the inclination the sides of the dome have to the horizon, and as previously explained.

In the truncated dome, however, such a joint exists (see the point marked $\pm B = 0$, in Fig. 32). Above this joint the ring stresses are compression, while below it, they are tension. A similar point, $\pm B = 0$, will be found in Fig. 33. The effect of the lantern load, however, overbalances, in this instance, the compressive ring stress in the compression zone, and all the courses are subject to tension, from the base of the lantern down to the base of the dome.

In conclusion, some stable forms of domes are submitted, in which there is no tension in any direction, except the tensional shear in the bed-joint of the lowest course. In each instance it will be necessary

* Rather say, "Joints of Equilibrium."

to resist the radiating pressure in this joint, and there only, by the tenacity of a hoop.

In masonry domes with a tension zone, the whole of this zone should be encased and covered by a sheet of metal, able to take up the tension stresses, B, in case the construction of tension courses, suggested previously, should prove too expensive.

In buildings of a monumental character, where money is of secondary importance, the designer should, perhaps preferably, use other means than the ones just mentioned to counteract the stresses in the tension zone. A ring of heavy masonry should encircle the dome from the "joint of equilibrium" down to the base. The dimensions of this wall should conform amply to the ring stresses, B, mentioned throughout this paper.

Reviewing past practices, in this respect, it is found that in only one of the famous ancient domes has the designer carried out this principle effectively and completely, namely, in that of the dome of the Pantheon, in Rome.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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DOCK IMPROVEMENTS AT LIVERPOOL.

Discussion.*

BY MESSRS. ALFRED NOBLE AND L. J. LE CONTE.

Mr. Noble. ALFRED NOBLE, President, Am. Soc. C. E.—This very interesting paper refers to a class of work which supplies a large field for engineering practice on the other side of the Atlantic. The magnificent dock system at Liverpool, developed to meet the severe tidal conditions there, has no parallel on our Atlantic coast, where the tidal range is much less and enclosed docks do not furnish the most economical solution of the problem of handling a large commerce. These different conditions render the paper all the more interesting, but, at the same time, make its general discussion difficult for American engineers.

The paper, however, describes many features of construction of great interest wherever subaqueous work is carried on, of which the speaker desires to note briefly two or three. The ingenious and successful method of laying dry the face and base of a wall to be underpinned, is worthy of most careful study.

The speaker had an opportunity, a few years ago, to see some of the work described, or some of similar character, in the vicinity, while in progress. The concrete was much wetter than is usual in this country, and might be described as sloppy. The materials were first mixed dry, and then, with the requisite amount of water, passed

*This discussion (of the paper by George Cecil Kenyon, Assoc. M. Am. Soc. C.E., printed in *Proceedings* for September, 1903, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. Communications on this subject received prior to January 23d, 1904, will be published subsequently.

through a very simple gravity mixer. A large graving dock, built of similar concrete and finished a year or two before, was visited and found in excellent condition. The chamber was about 900 ft. long, and the entire masonry more than 1 000 ft. long. In the entire length, only one small crack attributable to contraction could be found. In view of experience in this country, respecting the expansion and contraction of concrete with changes of temperature, this result seems remarkable. Until within a few years, specifications for concrete in this country usually required a mixture so dry that moisture would show on the surface only after hard ramming. English engineers freed themselves from this pernicious practice earlier than we did. Mr. Noble.

The use of wood for large lock gates seemed to the speaker remarkable when first informed of it, but it was stated that greenheart timber was teredo-proof and was considered even more durable than steel. At Liverpool the presence of sea water polluted by sewage renders the conditions particularly unfavorable for iron or steel, while the great durability of greenheart, and the greater facility with which timber gates can be repaired in case of accident, have apparently turned the scale in favor of wood throughout the entire system of docks at Liverpool. This practice has been followed at the Manchester Canal, but is not by any means general throughout Great Britain, while, on the continent of Europe, steel is generally adopted. A somewhat similar statement as to the relative durability of steel and wood was made to the speaker with respect to railroad ties on the Panama Railroad. These were of one of the many varieties of lignum vitæ. The timber is so hard that holes must be bored for spikes. The speaker was assured that many had been in service thirty to forty years, and were removed, not for decay, but because the rails had cut deeply into them. This durability is particularly noteworthy, in view of the rapid decay of ordinary timber in that hot, moist climate.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—Few harbor engineers in this country have had any experience in the line of work laid out for the proposed improvements at the Brunswick Docks, Liverpool. Nevertheless, this paper is extremely interesting, and is full of valuable instruction. Mr. Le Conte.

These vast harbor improvements were, no doubt, rendered necessary by the growing traffic in the Manchester Canal, which, at last accounts, was certainly detracting considerably from the natural growth of Liverpool Harbor. The magnificent masonry dock walls surrounding the different basins will certainly excite the admiration of all engineers. The writer thinks, however, that the American harbor engineer would do differently under somewhat similar circumstances. Instinctively, he avoids conflicts with uncertain foundations, and, instead of building a massive concrete dock-wall, would proceed to make the basin excavation, with a hydraulic dredge, to

Mr. Le Conte.

the required depth, allowing the natural slopes to take their own shape. The material excavated would be pumped into those portions of the work which needed filling. He would then build a pile structure from the top of the slope out to the foot, and then proceed to lay thereon the necessary railroad tracks and build proper freight sheds, etc., exactly as would be done in the case of a solid concrete masonry quay wall. Such a simple structure would be vastly cheaper, and, at the same time, answer all the practical requirements perfectly.

The query might naturally be made, would not the annual repairs on such a temporary structure be so great in amount as to impair its usefulness? The writer thinks they would not; inasmuch as the foundations of creosoted piles would not ordinarily need attention for fifteen to twenty years, and the chief item of expense would be in keeping up the repairs of the natural wear and tear of the wooden flooring of the wharf. This could be reduced materially by laying a wooden block pavement thereon, which would answer all the requirements of heavy traffic. When the time arrived for making repairs underneath the sheds, this could be done easily by means of a special pile-driver, built within the shed itself, by which the new pile could be hoisted up through holes made in the roof. By this means, all repairs to pile-work could be made cheaply, and without much inconvenience to traffic.

The author refers to faulty borings indicating 30 ft. to bed-rock, whereas it was actually found at 68 ft. The writer has had much the same vexatious experience, and he takes this occasion to state that, in all cases where the surface of the so-called bed-rock is at all irregular, there is nothing as misleading as a system of detached test-borings, so much so, that, in contract work, the engineer in charge too often wishes he had never made any preliminary borings. After all, they show absolutely nothing outside of the particular point at which each one is made, and, consequently, furnish really very limited information.

The writer is interested greatly in the many important details of construction described so clearly by the author. The practice has now become quite common to mix boulders with the mass of concrete, and thus save cement mortar to a very material extent. Where the concrete is laid in thick heavy masses the boulders can be placed not more than 20 ins. from each other and about the same distance from the forms, so as to insure good ramming between; thus the saving in cement becomes very great indeed, and, at the same time, does not detract in the least from the excellence of the concrete.

The author's statements, as to testing the cement before it was accepted, are very instructive and seem to cover the ground most thoroughly.

One feature, however, impressed the writer, *i. e.*, as to the richness of the concrete used in the dock walls. The poorest grade used

was 8 to 1, which the writer presumes means 1 to 2 to 6; *i. e.*, 1 to 2, mortar and 6 of the aggregates. This would seem to be abnormally rich for the plain massive dock walls, the main feature desirable being dead weight, the unit strength of the material being a secondary consideration; hence it is apparently uncalled for. Of course, in a large piece of work like this, a comparatively trifling variation in the proportions of the concrete would easily make a vast difference in the cost of the cement. That is where good sound judgment comes into play. Mr. Le Conte.

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PAPERS AND DISCUSSIONS.

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FILTRATION FOR PUBLIC WATER SUPPLIES, WITH ESPECIAL REFERENCE TO THE DOUBLE FILTRATION PLANT AT BREMEN, GERMANY.

Discussion.*

By Messrs. Morris Knowles, Allen Hazen, John H. Gregory, W. R. Copeland, L. J. Le Conte, J. P. A. Maignen and George W. Fuller.

Mr. Knowles.

Morris Knowles, M. Am. Soc. C. E.—This paper is interesting, for several reasons, and affords an opportunity of comparing European and American practice. It is particularly fortunate that there has been added to American literature the views of a European engineer on the subject of filtration, and information about a filter plant located in a country where so much attention has been and is being devoted to this subject.

It is interesting to note that the "number of bacteria in the effluent" is the accepted criterion of good work, rather than the "percentage of removal." This is to be commended, and should be accepted universally by students of filtration. A step further, and one which is receiving more recognition in America, where the size of the plants warrants expenditures for such studies, is the investigation into the pathogenic quality of the bacteria in the effluent, at least, in so far as this is indicated by the presence of *B. Colon Communis*, the representative bacterium of sewage contamination.

* Continued from November, 1903, *Proceedings*. See September, 1903, *Proceedings* for paper on this subject by Eugen Goetze, Esq.

Mr. Knowles.

It is not always true that high numbers of bacteria, above 100, in the effluent from a filter, indicate a water unfit to use for domestic purposes, if the large numbers in the raw water are due to decaying vegetable matter, and occur with a sudden rise in the stream. On the other hand, the character of the effluent, at times, may be damaged seriously and the health of the people endangered, even though the number of bacteria remaining in the effluent is not larger than occurs without causing comment; although, frequently, however, the presence of *B. Coli* is accompanied by large numbers in the effluent, but, perhaps, not more than are just as often present without such dangerous association. In the case of high rates with sand filters, the *B. Coli* test is particularly useful, and is more delicate than a general count in determining the suitability of the effluent.

Too great emphasis cannot be placed upon keeping in touch with the workings of the filter day by day. Of course, this is much more important with a rapid or mechanical filter, depending upon the use of a coagulant for its uniformity and stability of results; but it is also true, although to a less degree, with the slow sand filter, even though a lack of attention to the details of operation is not usually attended with such disastrous results as in the former case. For a small filter plant, where a technical laboratory man cannot be employed constantly, and where chemical and bacterial samples must be sent to outside laboratories for analysis, and thus such tests are made infrequently, the observation of the turbidity of the filtered water affords a ready and prompt means of determining its suitability for drinking purposes. Not only if mud, or finely divided clay, is passing through the filter, is it likely that more bacteria than usual will be present in the effluent, but it is also true that, after people are accustomed to a clear sparkling water, there is a decided dissatisfaction if turbid water be furnished, and it is proper and right to cater to this desire for a bright water, of pleasant appearance, even if a turbid one does not always indicate a less healthful water with more bacteria in it.

There is another peculiar factor, accompanying a large quantity of mud in the applied water, which the speaker has noticed several times, notably in Philadelphia, while in charge of the filter testing station, and for which he has not yet been able to present a satisfactory explanation; that is, that after a continued spell of muddy applied water, when the effluent begins to show signs of turbidity, the number of bacteria in it increases above the normal amount. This was true, even though the numbers in the raw water (probably due to dilution) were not always increased excessively, although generally somewhat larger than usual. In other words, high numbers in the raw water, when clear, were not accompanied by correspondingly high numbers in the effluent, but, on the other hand, high numbers (perhaps not as great as in the former case) if occurring with muddy water will almost always be accompanied by a great number in the effluent.

Mr. Knowles. In regard to the use of settling basins, the speaker cannot agree with the author that their use will not render it admissible to cut down the number of filters; nor does he believe that, in case of muddy water, settling basins can be dispensed with and more filters used, so as to operate at a lower rate. First, assuming that the applied water is muddy only at infrequent intervals, the use of the lower rate, in a case of having additional filters, or the use of the settling basins, will only be required a part of the time; thus, it is best to have the least expensive construction, viz., settling basins, which will cause lower fixed charges on that part of the plant in use only a part of the time. In the case of water being very muddy all the time, some means of coagulation may become necessary, which is accomplished best in settling basins. If settling basins of less capacity (probably about one-half) are required for continuous use, as compared with intermittent, quiescent operation, it can hardly be said that the result is the same in each case for an equal expense.

It is to be noted that the rate of filtration in German cities is much lower than in America, the maximum being lower than the average in most cases here. Recent investigations in America have shown that rates as high as 5 000 000 and 6 000 000 galls. per day to the acre, formerly thought quite excessive, can be used in many places with good results, when the water is not too muddy. It must not be thought, however, that it will be safe to run such high rates with all waters, and first a study must be made to ascertain the results from high rates for all seasons, before deciding upon its application in any given case. But the fact remains, that the German rate is about one-half or two-thirds as much as has been recognized as allowable for most waters in this country, and this is especially noticeable if the bacteria and turbidity given in the tables are a reasonable indication of the general average conditions abroad.

The author has carefully called attention to the fact that, in his practice, very high numbers of bacteria in the applied water are accompanied by poor results in the effluent. In the tables presented in the paper, this appears to be true of the effluent from the first filtration, although the highest numbers in the raw water are not as high as occur frequently in the waters of American rivers. It has been noticed in this country, however, that the character of the effluent remains practically the same, and low in the number of bacteria, even though those in the raw or applied water run up to hundreds of thousands, provided the river is not too muddy, as mentioned previously. In order to make this clear and show that the effluent of sand filters, when they are in good condition, is not proportional to the numbers in the applied water, the speaker had prepared two diagrams showing the results obtained at Pittsburg, Pa., and at Lawrence, Mass., with experimental filters. Both diagrams show numerous instances

when excessive numbers in the applied water are not accompanied by proportionately high numbers in the effluent, and in several cases are fully as low as the average of those which occur ordinarily in the filtered water. On the Pittsburg diagram, the turbidity of the river water is also plotted, and, in many instances, the high numbers in the effluent are preceded by muddy applied water. The injurious effects of the winter weather upon these exposed open filters stands out very clearly, and several instances of disturbances due to cracks in the walls, and manipulations occasioned by the experimental nature of the filters, are to be noted. On the whole, however, the general height of the effluent line is below 100 on the scale, except in severe weather, and it does not always follow the line representing the applied water. Scrapings and disturbances of all kinds are more noticeable on the Pittsburg diagram than on the Lawrence one, as the latter shows distinctly that the effluent remains in good condition practically all the time. It should also be noted that the Merrimac River water does not have such high bacterial counts and does not contain as much mud as the Allegheny. Mr. Knowles.

In reference to the depth of sand which in Bremen is allowed to remain in place before refilling, viz., about 16 ins., which is generally less than is allowed in this country, the writer does not state whether, at the time of such refilling, a large quantity of sand, say from 6 to 10 ins., is removed, or else shoveled over and placed on top of the fresh, or newly washed sand. This is the practice in this country, and is done so that there shall be no subsurface clogging, as will occur if a portion of dirty sand is left below a clean body of washed sand.

In regard to wasting the water from a filter immediately after cleaning, the speaker believes that in most cases this is an unnecessary refinement, unless the conditions are known to be unusual and likely to produce bad results. There is presented, in Table No. 7, the results of the first few days of several runs of the Pittsburg Experimental Filters, which show conclusively that the number of bacteria during the first 24 and 48 hours after scraping are not dangerously higher than those for five days, or indeed for the average of the whole period. In the cases given in the table, the rate of filtration for the first 24 hours after scraping ranged from 500 000 to 3 000 000 galls. per day, so that the applied water would appear in the effluent from 8 to 10 hours after starting.

In many of the instances where the numbers during the first two days are high, the applied water was more than usually muddy; in fact, the filter was put out of service, due to the quantity of mud, and quickly started again, which dosed a raw filter surface heavily and which need not occur in the operation of a municipal plant with the usual reserve area.

Mr. Knowles.

TABLE No. 7.—Results with Experimental Sand Filters at Pittsburg, Pa.

Showing Number of Bacteria per Cubic Centimeter in Effluents for each of the First Five Days after Scraping; Compared with the Average for the Run (omitting the Record on the First Day).

Filter No. 1.								Filter No. 2.							
No. of run.	Number of days run.	Number of bacteria in effluent. 1st day.	2d day.	3d day.	4th day.	5th day.	Average of run.	No of run.	Number of days run.	Number of bacteria in effluent. 1st day.	2d day.	3d day.	4th day.	5th day.	Average of run.
2	54	64	44	43	67	....	22	2	17	58	92	50	16	25	40
3	37	175	84	35	26	26	33	3	42	88	....	81	28	36	19
10	28	48	115	70	....	39	65	4	44	130	130	....	21	19	55
11	34	58	43	31	31	25	45	14	28	77	84	88	61	105	66
12	36	110	84	73	78	125	135	15	26	68	75	63	63	93	110
13	32	385	560	100	75	75	80	16	16	105	120	190	90	68	75
14	32	290	280	67	55	58	55	17	18	93	100	73	58	58	66
16	31	50	72	58	42	47	45	19	19	96	145	60	49	37	66
17	34	52	330	110	54	23	53	20	10	225	240	125	110	77	105
19	12	250	215	110	105	66	85	32	37	90	375	96	330	....	92
25	33	96	240	....	260	120	93	33	39	70	90	....	65	49	120
27	16	....	330	140	135	14	105	36	25	87	....	64	60	16	31
32	39	....	345	120	19	42	30	38	37	67	235	....	38	31	24
35	10	....	66	92	38	17	40	40	11	60	360	....	....	89	110
36	10	63	....	94	67	....	59	41	12	60	....	36	84	27	43
38	20	540	....	240	125	140	97	42	12	....	115	46	....	62	64
45	12	....	60	89	....	37	110	51	21	79	105	240	350	....	100
47	21	120	370	320	160	155	92	52	14	47	16	43	22	....	115
48	18	15	31	25	24	22	33	53	16	73	92	35	22	....	29
49	19	10	....	48	20	22	23	54	21	61	201	....	120	120	51
50	17	215	145	105	....	92	82	56	17	150	....	57	69	40	68
51	14	....	48	16	36	17	30	57	15	140	57	17	18	9	37
52	16	....	81	35	12	32	24	58	16	165	44	20	42	....	65
53	12	115	97	78	22	60	45	59	19	67	42	....	22	29	28
54	13	....	39	25	47	23	30	60	18	165	58	12	15	....	23
55	18	14	....	80	17	23	50	61	17	....	62	17	19	12	24
56	17	750	125	64	13	....	30	62	28	29	280	130	31	....	56
57	18	43	....	6	21	22	16								
58	25	69	80	195	94	....	63								
Averages	....	160	160	88	62	52	58	Averages	....	94	135	74	72	50	62

The same story is told by the results obtained with the Lawrence, Mass., City Filter, as tabulated by Charles G. Hyde, Assoc. M. Am. Soc. C. E., and the speaker.* It may be seen here that the difference in the character of the effluent before and after scraping, even with most of the filter surface disturbed, practically does not amount to anything. It is important to dwell upon this point because of the fre-

* *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 304.

quent and erroneous statements made, that the effluent from a sand filter must be wasted for some little time after scraping. All such precautions, while duly conservative, diminish the yield and filter capacity unnecessarily. It is much better, in the speaker's opinion, if such precaution is necessary, to provide a reserve filter area, which is needed for many other reasons, and depend upon a short period of rest after filling and then start with slow accelerations in the rate. Mr. Knowles.

The above statement can be applied to double filtration, especially in reference to waters containing no higher numbers of bacteria than appear in the tables presented by the author. For, while the effluents of the preliminary filters cannot be considered satisfactory, as given, it appears unexplainable to the speaker why better results, or as good as found in the final filter, should not be obtained with a raw water no worse than is shown. The author states that a double filter is never an error. While this may be true, from the scientific and bacterial standpoint, the monetary phase must be considered, and many places, now having water improved by filtration, would never have thought it possible to incur the expense of purification if double filtration, meaning almost double the cost, were necessary. In this country, with the lavish use of water, occasional demands for maximum quantities, frequently 25 or 30 % greater than the average, are just as likely to come at a time when a sudden downpour, or rainy weather, has produced a muddy stream. While it is generally true that turbid waters occur in the spring and fall, the most difficult waters to treat are frequently seen in the winter, or in the midst of summer weather, when the demand for water to prevent freezing of pipes (in the first season) and for sprinkling purposes (in the second) has brought the use to the maximum. Thus double filtration in America means twice the filter area.

The statement, that double filtration has always succeeded in providing perfectly clear water, is a gratifying one; but the speaker wonders whether sedimentation, either with or without coagulation, as the necessity demands, with one filtration, would not have produced the same result at a less total cost. The use of a coagulant is an expense solely at the time of application, while the fixed charges for additional filters is a constant source of drain. It is surprising, to say the least, referring to Page 783,* third Paragraph, that any one should think of double filtration for a water which has come from the first filter with only 40 bacteria per cubic centimeter.

The use of automatic devices, both on the inlet and outlet, is to be commended. This is especially true as the novelty of such works for the purification of water is disappearing and mankind is proverbially accustomed to grow careless with familiarity and less likely to be watchful of changes. The size, also, of some of the recent plants be-

* *Proceedings*, Am. Soc. C. E., for September, 1903.

Mr. Knowles.

ing built in this country, renders it imperative that the number of gates to be attended to, and the number of things to be done each day, shall be lessened as much as possible.

It is interesting to note that the allowable loss of head in Bremen is about 27 ins., while, in this country, 48 ins. is deemed advantageous. While 16 ins. is the minimum depth of sand allowed, 24 to 30 ins. is the usual figure in this country. The filters here commonly have 48 ins. of sand, when filled to maximum depth, and also the same depth of water over the surface.

The sand removed at each scraping is somewhat in excess of that in this country, being from $\frac{3}{4}$ in. to $1\frac{1}{8}$ ins., the lower figure being the same as at Lawrence, Mass., the highest published figure in this country for a municipal plant, the average at the Pittsburg Experimental Filter Plant being about 1 in. The speed of scraping, also, is rather less than in this country, and, from the statements, other operations seem to be in harmony with this. From this, it may be reasoned that the low cost of all operations, viz., $1.52 per million gallons, is due, more than anything else, to the low cost of labor, which is only about one-third to one-half of that in this country.

A tabulation of the various costs and quantities is given in Table No. 8, and compared with the data relating to some American filter plants, most of which have been taken from *Transactions*.*

The statements relative to sand washing are quite instructive, especially to American engineers, for the speaker does not know of the use of the drum washer, at least at filter plants in this country. Statistics as to the cost of washing per cubic yard would be of interest, although it may be expected that, with the quantity given as being washed per hour and the number of men in attendance, this cost will be low. It seems as if the services of more than one man would be necessary to bring sand to the washer, to attend to the operation of the machine and to carry sand away to the pile of clean material; all of which items are in this country charged to washing. The author is in error, however, in supposing that 20 to 30 volumes of water are needed with the ejector type of washer, for in more than one place in this country 10 volumes are all that are used, and, in some instances, suffices for all the operations of washing, from carrying the sand from the dirty pile to the washer and finally delivering to the pile of clean sand ready for use.

The drum type of washer does not lend itself readily to the method of transmission of sand by water to and from the washer, which is the line in which the most advanced progress is being made in this country to-day; even now, sand can be taken from the piles in the filter without the use of wheel-barrows. The nearest approach to this, with the drum washer, within the speaker's knowledge, is the use of the Greenway

* *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 258.

washer, at the East London Water-Works (which, by the way, washes 5 cu. yds. per hour), where the Engineer, Wm. B. Bryan, M. Inst. C. E., has installed two ejectors, to be used with the washer, one at the filter to receive the sand as scraped and send it to the washer, and one at the outlet of the washer to convey the clean sand to another filter. This arrangement, however, means additional expense, simply for throwing capacity, which might just as well be used in washing and is thus utilized with the ejector type of machine. Mr. Knowles.

TABLE No. 8.—SUMMARY OF DATA FOR SEVERAL SLOW SAND FILTERS.

Items.	Bremen, Germany.	Lawrence, Mass., City Filter.	Lawrence Experimental Filters of Massachusetts State Board of Health.		Albany, N. Y.	Mount Vernon.	Pittsburg Experimental Filters.
			3-*B*.	8-*A*.			
Time included.....	1900–1902	1893–1900	1893–1899	1893–1899	1899–1900	1896–1900	1897–1899
Average rate, in millions of gallons daily.	1.70	1.25	2.35	2.77	2.60	1.70	2.90
Average period between scrapings, in days	32	29	26	29	25	24	23
Average yield, in millions of gallons daily, between scrapings..	55	36	62	80	66	41	68
Scrapings per year...	11	13.3	13.8	12.6	15	15	17
Average number of inches removed at each scraping.....	0.98	0.75	0.49	0.53	0.71	0.61	1.05
Cubic yards per acre removed at each scraping.....	132	100	65	71	95	82	141
Hours of labor for each scraping and wheeling out	336	228	.....	.....	176	.....	.....
Sand washed, in cubic yards per hour.....	2.61	0.58	.....	.....	0.64	.....	.....
Volume of water to sand	7 to 8	10	.....	.....	12.5	.....	.....
Hours of labor sanding per cubic yard	2.5	1.5	.....	.....	1.3	.....	.....

ALLEN HAZEN, M. Am. Soc. C. E.—The Society is to be congratulated upon receiving a paper from Mr. Goetze. In the last few years a number of American water purification plants have been described before it, and the speaker thinks it most profitable to consider the developments, in another country, toward the same end, namely, the complete purification of water, but which, as the paper shows, have taken somewhat different lines from those followed in recent American plants. Mr. Hazen.

The speaker has had the pleasure of visiting the Bremen filters and of meeting Mr. Goetze, and seeing his most ingenious and satisfactory methods of water purification, and, therefore, can appreciate the paper more fully.

Mr. Hazen. The Weser rises in the Hartz Mountains and flows northward through the flatter country before reaching Bremen. The character of the water is much like that of the Hudson at Albany.

The size of the water-shed of the Weser and the urban population upon it, in comparison with some American streams, are given in Table No. 9.

TABLE No. 9.

City.	River.	Drainage area above intake, in square miles.	Urban population per square mile in 1900 (towns with more than 4 000 inhabitants).
Philadelphia	Schuylkill	1 915	98
Bremen	Weser	15 100	About 70
Lawrence	Merrimac	4 634	69
Albany	Hudson	8 240	46
Philadelphia	Delaware	8 186	30
Pittsburg	Allegheny	11 400	16
Washington	Potomac	11 476	7

The data as to the drainage area and urban population upon the Weser are less accurate than for the American streams. It would be appreciated if the author could furnish more exact data upon these points.

The Weser is like the Hudson, in that it carries a little peaty matter. Its turbidity seems to be about the same. It is certainly more turbid than the Merrimac at Lawrence, probably less turbid than the Allegheny at Pittsburg, and very much less turbid than the Schuylkill and the Potomac. The drainage area is a little larger than that of any of the American streams mentioned. The urban population per square mile gives it a place above the average, but not at the top of the list. The closeness with which the raw water approaches the waters of these American streams gives an added interest to the methods of purification used.

It is particularly interesting to note that the Bremen filters are open. Mr. Goetze takes this as a matter of course, and does not mention cold weather as one of the causes of reduced efficiency at Bremen, although he speaks of the necessity of covering in more severe climates, about which there can be no question. It is interesting to note that the winter temperature at Bremen is substantially the same as that of Philadelphia and Pittsburg. Evidently, Mr. Goetze, who, of course, is familiar with the operation of covered filters, for there are many such in Germany, does not regard this winter temperature as one requiring covers for filters.

The speaker believes experience shows that, for this and warmer climates, covers are to be regarded as a luxury rather than as a

necessity; that is to say, with good management, open filters can be operated with as good results as covered filters, and without any great increase in the cost of operation. In fact, in some respects, open filters lend themselves more readily to labor-saving machinery for sand-handling than do covered filters. Mr. Hazen.

Probably the most important advantages of covers, in climates of the severity of those mentioned, is the possibility of employing the men every working day in the year, with the economies which come from their constant and regular employment.

The most striking feature of the paper is the method of partial double filtration. The author notes that when filters are scraped, that is to say, when the top layer of dirty sand is removed, as it must be occasionally, to maintain the service, the efficiency of the filter afterward is much decreased, and after the sand has been reduced in thickness, and washed sand is replaced to restore it to its original depth, the effluent thereafter for some time is of worse quality than that obtained otherwise. This decrease in efficiency has been noted everywhere where sand filters have been studied closely.

To see how much influence these factors have had on the results at Albany, all the data bearing upon these points, which include the daily bacterial counts before and after scraping and refilling since the plant was put in operation, have been compiled and averaged. The figures were taken from the very complete records kept by Mr. Leonard M. Wachter, Chemist and Biologist of the plant, and for them the speaker is indebted to him.

The averages of these figures are given in Table No. 10.

TABLE No. 10.—AVERAGE NUMBER OF BACTERIA IN EFFLUENT FROM ALBANY FILTERS BEFORE AND AFTER SCRAPING, AND BEFORE AND AFTER REPLACING SAND, FROM SEPTEMBER, 1899, TO SEPTEMBER, 1903, INCLUSIVE.

	256 scrapings during the 8 warmer months (April to November).	115 scrapings during the 4 colder months (December to March).	Fourteen refillings.
Third day before	44	194	68
Second day before	48	213	52
Last day before	62	272	68
First day after	91	386	498
Second day after	74	741	570
Third day after	82	1 100	444
Fourth day after	91	1 468	461
Fifth day after	82	1 312	586
Raw water	14 500	74 800	25 200
Mixed effluent	60	596	131
Average efficiency of whole plant for the same periods	99.58%	99.20%	99.48%

Mr. Hazen. From the summary given in Table No. 10 it appears that the decrease in efficiency following scraping during the eight warmer months of the year is very slight. Often, no decrease whatever is observed. This has been particularly true in the latter part of the period. On the general average for the whole period, the increase in the number of bacteria after scraping, although noticeable, is not large enough to be serious.

In the four colder months, the conditions are quite different. After scraping, the number of bacteria reaches, on an average, a maximum of about seven times the number present before scraping, and this high number persists for a number of days, and the additional number of bacteria is so considerable that, apparently, the number of bacteria in the mixed output for the four months is two or three times as great as it would be if the efficiency could be kept up to that obtained just before scraping. As it is, the filters, during the winter months, with very high numbers in the raw water, have given an efficiency of about 99.2 per cent, If the decreased efficiencies following scrapings could have been eliminated entirely, the average winter efficiency would have been 99.6 or 99.7%, or equal to the actual average summer efficiency.

The decrease in efficiency following the refillings with sand is quite as marked, but, owing to the much smaller number of such periods, the effect upon the average output is comparatively small. Some refillings are accomplished with no more disturbance than summer scrapings; at other times, much higher numbers are found in the effluents following the operation. The results are so erratic as to suggest strongly that many of the bacteria found in the effluents after refillings are due to growths in the underdrains and sand during the period of a week or more that the filter is out of service. As far as this is the case, the high numbers are rather misleading, for bacteria which occur in this way are entirely harmless.

The method proposed by Mr. Goetze is to filter a second time the effluents containing more than the normal number of bacteria. This is an entirely logical proceeding, and probably the best way of accomplishing the result. Double filtration has been used in a number of cases. The works at Schiedam, in Holland; those of the Grand Junction Water Company, at London, and, more recently, those at Zurich, are among the best known. Two sets of filters have been used in these cases, the first-filters and the after-filters being at different levels and of somewhat different construction.

At Altona, double filtration was introduced in a somewhat different form. The rules of the German Government required effluents to reach a certain standard of purity, and required that when effluents were not of this quality they should be wasted. The filters at Altona were on a hill, from which the city was supplied by gravity. The

preliminary pumping was thus more expensive than usual; and to waste the effluent represented a greater increase in the operating expenses. Centrifugal pumps were installed to pump that part of the effluent not of satisfactory quality back into the filters, to be filtered over again. This arrangement was an improvement; but Goetze's siphons, with the filters all at one level, made the use of centrifugal pumps unnecessary, and, in this respect, was a distinct advance over the Altona arrangement. His process is patented in Germany, but the speaker believes it is not patented in the United States. Mr. Hazen.

When the speaker examined Mr. Goetze's apparatus at Bremen, and the records of operation obtained with it, in 1896, he was impressed with the idea that a most substantial step forward in the art of water purification had been made; and if he could have been sure of securing the same faithfulness in operating the plants with which he has been connected as can be generally depended upon in Germany, he would, undoubtedly, have made use of this device in several cases. His reason for not using it was this: The siphons work equally well forward or backward, and, with careless or vicious attendants, they may be operated thus; that is to say, raw water can be run into the filtered-water pipes through them, and, in fact, this will happen if the siphons are started with the water levels in their normal condition. It is only by lowering the water on one of the filters, and making the conditions to that extent abnormal, that they can be operated as intended.

It has been the speaker's custom to design filter plants practically or entirely without by-passes. At Albany, for instance, there is no possible pipe connection for sending raw water to the pure-water pipes. The only way that this could be done would be to dig up the sand layer somewhere, an operation of some difficulty, which would require some time, and which would be apparent to anyone who happened to be present and who understood the construction of filters.

With the siphons placed as under the author's patent, it would be possible at any time for an attendant to send raw water into the filtered-water pipes, and this could be done during the hours of the night and absolutely no trace of it would be left in the morning. The attendant might do this because he was too lazy to make the changes in the gates necessary to maintain the supply of filtered water.

In the past the speaker has been unwilling to take the chances of an unauthorized use of a by-pass, but systems of filtration are now coming into use which, in much higher degree, depend upon the faithfulness of the attendants, and the use of the siphons is certainly as safe a procedure as the application of a coagulant, where the efficiency of filtration depends upon it.

Mr. Hazen. If the use of siphons in the Goetze system would increase the winter efficiency of a filter plant from 99.2 to 99.6%, as the results obtained at Bremen, in connection with a study of the Albany figures, indicate, it may be considered seriously whether the advantage is not enough to counterbalance the possibility of the objectionable use of siphons; but it should be remembered that if the filter were by-passed, even for one night, the number of bacteria sent to the city would be much larger than the number eliminated by the second filtration during the whole course of a winter.

Practically, the speaker is inclined to think that the procedure of starting filters at a lower rate than the nominal, if carried out with the same increase in filtering area that would be necessary for double filtration, would prove a very effective treatment, and would perhaps increase the quality of the output to a corresponding extent. The first effluent has never been wasted at Albany, and, as far as the speaker's observation and inquiry go, wasting the first effluent has been a theoretical, rather than a practical, matter. It has been advocated by certain persons, but, practically, it has never been followed systematically in any water-works, as far as the speaker knows, because it is both better and cheaper to start the filters at reduced rates, and to make the rates as low as the conditions permit, and as are shown to be advantageous.

The discussion serves to emphasize the fact that filtration produces a relatively, but not an absolutely, pure water. The standard of purity of public water supplies has increased in the past, and there is every reason to believe that it will increase further in the future; and that the methods which appear satisfactory to us to-day will seem as inadequate a generation hence as some of the older methods seem to us to-day. The art of water purification is bound to advance to meet these requirements, and methods of purification more efficient than those in use to-day will be required, and will be developed gradually.

Mr. Gregory. JOHN H. GREGORY, Assoc. M. Am. Soc. C. E.—The speaker has been very much interested in this paper, and also in the discussion which it has brought forth, particularly that relating to the washing and transporting of sand. Mr. Underwood's discussion on the transporting of sand at the filters in Philadelphia and the results obtained has been of especial interest, inasmuch as the method in use there is the one which was recommended by the speaker.

The author, evidently, does not favor the ejector type of sand washer, but, in this country, this type is in almost general use, and, in the speaker's opinion, is here to stay. It may be of interest to give briefly a little of the history of the ejector washers in this country, and also of the development of the method of transporting sand by water.

The first washer of which the speaker has any record was built at the filter at Lawrence, Mass., early in 1895, and was first put in use

on June 17th. This washer consists of four hoppers fitted with horizontal nozzles. In 1897 and early in 1898 Morris Knowles, M. Am. Soc. C. E., who was then a member of the Lawrence Water Board, began experimenting with different arrangements for transporting sand, and, as a result of these experiments, a portable hopper or ejector was built and put in regular use in July, 1898. This ejector, however, was not, and has not been, used for transporting sand from the filter, but for transporting sand to the washer after it had been wheeled up to the bank beside the filter. Mr. Gregory.

At the filters at Poughkeepsie, N. Y., in 1895, and also again in 1896, a single-jet washer was used,* according to Mr. Charles E. Fowler, the superintendent. In November, 1897, a double-jet washer was used. No drawings of either of these washers are given, but, from the description, presumably, they are of the ejector type fitted with horizontal nozzles. From the jet in the bottom of the second hopper of the double washer, the water and sand were transported about 130 ft. to a tank over one corner of the filter. The dirty water flowed off from the top of the tank and the sand was discharged on the filter through a valve in the bottom. In August and September, 1897, it became necessary to provide some new sand for the old filter at Poughkeepsie. This sand was delivered in scows alongside the dock near the filters. Mr. Fowler designed a movable ejector which could be lowered into the scows and into which the sand could be fed. The sand was lifted 30 ft. by this ejector and transported 630 ft., through a 4-in. cast-iron pipe, to a tank, the dirty water overflowing from the top of the tank and the sand being discharged through a valve in the bottom, and then spread over the surface of the filter.

In 1902 it became necessary to purchase additional filter sand, and, for transporting the sand from the dock to the filters, a method similar to that used in 1897 was adopted. In this case, however, the sand was first hoisted 20 ft. by the buckets ordinarily used for hoisting coal, and then fed into an ejector. From this ejector the sand was transported 600 ft., through a 6-in. cast-iron pipe, to the filters.

In 1897, when Allen Hazen, M. Am. Soc. C. E., designed the Albany filters, he included two washers of the ejector type. These washers each have five hoppers fitted with vertical nozzles. The details of these washers were worked out, by William B. Fuller. M. Am. Soc. C. E., and the speaker, from rough sketches made by Mr. Hazen.

It was while the speaker was connected with the Albany filters, and also after reading the Poughkeepsie report for 1897, that he first became interested in the washing and transporting of sand. The subject of transporting was very fully discussed by Mr. Fuller and the

* In a paper on the Poughkeepsie filters, before the New England Water Works Association, in 1898.

Mr. Gregory. speaker at various times from 1897 to 1899, and numerous methods were worked out in enough detail to know that they were perfectly feasible. From their studies they concluded that the ejector method was the most promising, the only difference of opinion between them being in the design of certain details.

In the fall of 1899 the Albany filters were started in operation before the construction work was entirely finished, and for a period of several months the speaker had the opportunity of studying in detail the transporting and washing of sand as carried on there. As is well known, the sand is wheeled out from the filters to the court and then put through the washer. After watching these operations he became convinced that by adopting the ejector method a great improvement could be made in the transporting of the sand, together with a material reduction in the cost of operation.

Before leaving the Albany work, the speaker made the suggestion that while it might not be possible at that late date to make the additions and changes necessary for installing the piping, so that ejectors could be used in the filters, it would be possible in the court to transport the sand to the washer and take it away to a storage pile by means of water.

Early in 1900, George I. Bailey, M. Am. Soc. C. E., who was Superintendent of the Albany water-works at that time, designed and had built a small portable ejector which was used for transporting the sand to the first hopper of the washer. The operation of this ejector was very satisfactory, not only in decreasing the cost of washing, but also in increasing the capacity of the washers. The washed sand, however, was not taken away by water, but was wheeled away, as had been the common practice.

Shortly after the speaker became connected with the filtration of the water supply at Philadelphia, in the spring of 1900, he was asked by George S. Webster, M. Am. Soc. C. E., who was the Chief Engineer at that time, what he considered the best means of handling the sand to and from the filters, and he replied that he would use the ejectors for handling it from the filters and that he felt that it might be possible to handle it in a similar manner back into the filters. At that time, he felt that it might be better to provide stationary ejectors in the filters ready for use at once, but on further study he came to the conclusion that portable ejectors would be more practicable.

The problem of designing a system for transporting sand from the Philadelphia filters was such a large one that the speaker felt that there ought to be some experimental data on the subject, and in August of that year he suggested that an experimental machine be built for obtaining such data. After some delay, a machine was built and a series of experiments made, from July to November, 1901, under his direction. This machine consisted of two hoppers fitted

with horizontal nozzles and a long discharge pipe. It is to be regretted that the results of these experiments have never been made public. While they were not complete, by any means, they threw considerable light on the subject, and demonstrated amply that sand could be transported about 400 ft. with a lift of about 13 ft., and with an economical use of water. Mr. Gregory.

The sand washers at Lower Roxborough, which Mr. Underwood has described, were designed before, and those at Upper Roxborough after, the experiments just mentioned were made.

At the time the speaker suggested making the experiments, he felt that it would be possible to go a step further than just transporting the sand to the washer; that is, that the sand could be taken from the machine, the last hopper acting as an ejector, and transported by means of water back into another filter which was being refilled with washed sand.

It would not be practicable, however, simply to dump the sand on the filter, allowing it to spread itself, and letting the water run away to a drain, as there would probably be considerable trouble in the subsequent operation of the filter.

When sand is discharged by means of water, and allowed to spread out, the finer particles separate from the larger ones and the sand is found to be stratified. Furthermore, the water will be more or less turbid, and, as some ponding would take place, a certain amount of sediment would be deposited. Should sand be replaced in a filter in this manner, subsurface clogging would be sure to take place when the filter was put in operation. To obviate this difficulty the speaker believes that he is the first to suggest that the sand should be discharged into a tank, somewhat similar to the one used by Mr. Fowler at Poughkeepsie, but which could be moved from point to point in the filter. The water would be allowed to overflow at one end and would be carried away by a pipe to the drain provided for the purpose. The sand would be discharged through a valve in the bottom of the tank directly into wheel-barrows and then wheeled away and spread.

It was found, in the experiments at Philadelphia, that wet sand could be loaded successfully into a perforated wheel-barrow through an opening in the bottom of a tank filled with sand and water, provided the effective size of the sand was not very small. At present, in Philadelphia, sand is not being transported back into the filters by means of water, but the speaker understands that the method is soon to be tried.

At the experimental testing station in Philadelphia, in the summer of 1901, a sand washer was built for use in connection with the experiments which were being made on the filtration of water. This washer is an exact duplicate of those at Albany, having been made from the same patterns.

Mr. Gregory.

At the filters in Mt. Vernon, N. Y., in 1897, a washer was designed and built by Mr. A. H. Kneen, the engineer in charge there. This washer consisted of four hoppers fitted with horizontal nozzles. In 1900 a second washer was built similar in general design to the first one.

At Cincinnati, Ohio, while the experiments were being conducted on the filtration of water, a washer was built, early in 1898, under the direction of George W. Fuller, Assoc. M. Am. Soc. C. E. This washer had four hoppers, and was fitted with horizontal nozzles.

At Milford, Mass., a small filter plant was designed and built in 1902 by Leonard Metcalf, Assoc. M. Am. Soc. C. E. At Mr. Metcalf's request, a sand washer and a portable ejector, for use at that plant, were designed by the speaker. This washer consisted of only two hoppers and was fitted with horizontal nozzles. The speaker regrets that, at the present time, he is unable to give any figures relating to the transporting and washing of sand at this plant.

The speaker believes that, when an ejector is used in connection with a washer, two hoppers in the washer are ample for washing the sand. In fact, he thinks that satisfactory results may be obtained with one hopper. When sand is transported a considerable distance through a pipe, it gets a good washing, and if, when discharged into the hopper, the dirty water can be carried away quickly, the sand will be found to be nearly clean. The additional washing which the sand receives in passing through the hopper should be sufficient to make it clean enough for all practical purposes.

In the designs for the proposed filters at Pittsburg, Pa., made in the winter of 1901 and 1902 by Mr. Hazen and Mr. Knowles, provision was made for transporting sand from the filters to the washers by means of ejectors. These washers were to have consisted of two hoppers fitted with horizontal nozzles.

At New Haven, Conn., filters are now being built by A. B. Hill, M. Am. Soc. C. E., for the New Haven Water Company. The general designs for this work were furnished by Mr. George W. Fuller, and it was at the suggestion of Mr. William B. Fuller and the speaker that he recommended the transporting of sand from and to the filters by means of water; and to them was entrusted the design of the apparatus for transporting and washing the sand.

In the design of this plant, in which the filters are covered, a radical departure from previous practice has been made. There will be no so-called court, but instead, a long covered pipe gallery with the filters ranged on either side. In this gallery will be placed the apparatus for washing sand. No sand will be stored, as it is proposed to transport it directly from the washer back into some filter which will be always kept in reserve for receiving washed sand. Only one washer will be provided, consisting of two hoppers fitted with horizontal nozzles, and mounted on trucks so that it will be movable. In

operation, this washer will be placed half-way between the filter from which the sand is being transported by means of ejectors and the filter which is being refilled. Mr. Gregory.

In this filter will be placed a movable receiving tank which can be supported from the roof of the filter at various points. The dirty water will overflow into a chamber in one end of the tank and will be carried away through a light, spiral, riveted-steel pipe. It is expected that at this plant a considerable reduction in cost of maintenance will be obtained.

It should be stated that the method of operation just outlined is mainly applicable to covered filters, but it is equally applicable to open filters in a climate where the sand will not freeze in winter.

WILLIAM R. COPELAND, Assoc. Am. Soc. C. E. (by letter).—In his interesting paper on the water filters of Bremen, Mr. Goetze has pointed out, that, if sand filters are used to purify clay-bearing waters, the effluents will not be clear unless the raw water applied has been clarified partially by passing it through preliminary filters. Mr. Copeland.

The City of Philadelphia is carrying on a series of experiments with preliminary filtration, and it may be interesting to note the effect which such a method of treatment produced on the volumes of water that the secondary or slow sand filters purified in a few instances between scrapings.

As the water of the Schuylkill River often carried large quantities of clay, etc., the raw river water was passed through beds of filtering material at rates which varied from 60 000 000 to 110 000 000 galls. per acre per day during these experiments. Even at these high rates, the preliminary filters took from 50 to 70% of the foreign matter out of the water. The solids in suspension were not always reduced to 50 parts per million, however, which is about the limit that slow sand filters can handle in a satisfactory manner.

The data in Table No. 11 have been selected, therefore, because they give a good idea of the effect which different quantities of suspended matter in the applied water had on the amounts of water filtered between scrapings.

TABLE No. 11.

Slow sand filter No.	Turbidity of the applied water, in parts per million.	Millions of gallons filtered between scrapings.	Nominal rate of filtration, in millions of gallons per acre per day.	Maximum loss of head, in feet.	Effective size of sand, in millimeters.
7	56	236	6	3.6	0.41
7	5	849	6	3.0	0.41
B	627	20	6	5.7	0.42
B	28	400	6	5.0	0.42
B	56	177	10	6.1	0.42
B	12	963	10	6.3	0.42

Mr. Copeland. The water applied to these filters was "pre-filtered" Schuylkill River water. Filter No. 7 and Filter B were composed of beds of sand supported by layers of gravel, and the filters were run in a careful and scientific manner. The figures in Table No. 11 show that, when the applied water contained more than 55 parts of suspended matter per million, the filters were only able to purify about 200 000 000 galls. per acre between scrapings; but when the suspended matter in the applied water was reduced to 12 parts or less per million, the filters purified more than 800 000 000 galls. per acre between scrapings.

As the preliminary filters remove the coarser particles of suspended matter from the water, it follows that the particles of foreign matter in the effluent are very small. Such very small objects find their way easily between the grains of sand, and do not clog the filter to any considerable degree. For that reason the loss of head increases at a slow and irregular rate, advancing on one day and falling back the next. In order to show how differently a filter will act, in this respect, the losses of head, for Filter No. 7, at 12 o'clock noon, of each day of the periods referred to in Table No. 11, are plotted in Fig. 1.

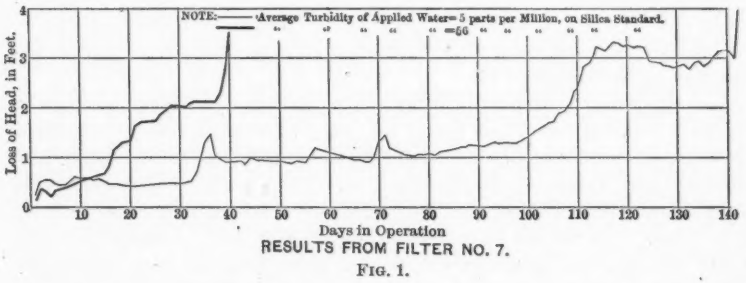


FIG. 1.

By an examination of Fig. 1 it will be seen, in the first place, that the loss of head increased more slowly, and, in the second place, that it increased much more irregularly, when the applied water contained 5 than when the applied water contained 56 parts of suspended matter per million gallons of water.

Moreover, the filter would probably have run for several days longer in the first case if pre-filtered water had been applied after the 142d day. On the morning of the 143d day, however, raw river water was turned on the filter, and within two hours No. 7 went out of service.

The lessons taught by these figures and the diagram are:

First, that when a river water has been well clarified by passing it through efficient preliminary filters, slow sand filters will complete the purification at rates of 6 000 000 galls. per acre per day, or double the usual rate.

Second, that slow sand filters will treat very large volumes of a well-clarified water before the maximum loss of head develops. Mr. Copeland.

Third, that the process of preliminary treatment must be very thorough in order to secure the most economical results.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The writer is greatly interested in this most instructive paper. The happy results obtained are increased in value by reason of the fact that they are the results of well-tried experience, and are therefore entirely free from mere speculation. It seems to the writer that the author has certainly taken an important forward step in the art of sand filtration, and has opened up an entirely new field for future development, which can hardly be overestimated, either in its extent or in the importance of the results. Every true student of sand filtration will hail with delight any reliable effort made in the art which will tend toward the avoidance of the use of chemicals for precipitation. The results at Bremen with water from the Weser—which seems to be quite muddy during storms—show conclusively that in that case the use of chemicals was entirely unnecessary. It remains to be seen to what extent this very important principle can be pushed with economy and safety. Now that the facts have been well established by experience, it remains for someone to come forward and explain. Mr. Le Conte.

After reading over the results one can hardly escape the conclusion that, after all, the good work done is simply one of natural avidity. During ordinary stages of the river, the raw water contains no more food than the colloidal film—covering the upper surface of the filter—can get away with conveniently. During flood stages, the raw water is more heavily charged with food products than the colloidal film can conveniently get away with, and, consequently, the film germs get more food than they actually need, and, therefore, allow it to pass through with the filtrate.

Not so with the second filter, which is fed with the filtrate from the first filter. Here the film is fully developed and ripened with raw water before it is put into service as a second filter, and, subsequently, it is fed with the first filtrate, which is necessarily lacking in food products. Hence the film germs are naturally fierce and hungry, and consequently attend to their duties with much avidity, and the result is a high-grade second filtrate. This would seem to be a reasonable way of looking at it; at all events, it is offered as a possible explanation of this most important phenomenon.

These interesting results, among other things, hold out pleasing hopes for the turbid water supplies from the southern rivers, but the news seems to be almost too good to believe fully that such a simple procedure could possibly overcome the great difficulties contended with at Cincinnati, St. Louis and New Orleans. The writer has no doubt that double filtration would certainly palliate, very largely, the

Mr. Le Conte. troubles, but, nevertheless, he thinks that possibly triple filtration might be found to be necessary.

The author's automatic regulators for controlling filtration are very ingenious in design, and are worthy of high praise for their simplicity in detail.

The operating expense of double filtration, given by the author as $1.52 per million gallons, is most remarkable for economy, as it means, approximately, $3.04 per million gallons in this country, which is far less than one would naturally expect.

The Society is greatly indebted to the author for this most valuable paper.

Mr. Maignen. J. P. A. MAIGNEN, Assoc. Am. Soc. C. E.—This paper is very interesting, not only because it contains a practically new idea in the management of slow sand filter beds, that of filtering a second time the filtered water when it does not come up to the desired standard, but also because it deals with a number of questions which may be discussed with advantage, for instance:

The best test to apply to filters;

The influence of bacteria in the process of water purification;

The "ripening" of filters;

Whether or not all the dirty sand should be scraped;

The speed of filtration;

The meaning of the words, "preliminary" and "final" filters, etc.

The discussion of this paper will, no doubt, bring out much useful information and reveal some of the progress made in the art of filtration during the last few years.

The author suggests that "the bacteriological examination of every filter should be made daily, if possible." In great cities like Philadelphia, New York or Washington this is possible, but in small towns, where the resources are limited, it is not practicable. The speaker, however, thinks that all public water supplies, large or small, should be examined bacteriologically at least once a month and preferably once a week, and he suggests that periodical qualitative analyses of the raw water and of the filtered water (as it enters the distribution mains) would be productive of more good than the daily quantitative test of each individual filter.

To this should be added some simple chemical tests for the detection of organic matter and chlorine, which would indicate immediately any extraordinary pollution of the water supply, upon the ascertainment of which, public authorities should seek and abate the nuisance.

The qualitative analyses will show the kinds of bacteria which pass through the filters, and establish whether or not the purification is complete. If it be found incomplete, those in charge of the works will be induced to look out for improvements. At present it seems to be

granted that a certain number of *Colon Bacilli* may pass through the filters without impairing the potability of the water. If the speaker were responsible for the management of a public water supply, he would not rest until the system or systems of filtration used were so perfect that they would give a final filtrate entirely free from *Colon Bacilli*. Mr. Maignen.

The speaker agrees with the author as to the advantage of a physical test, or turbidity observation, because it gives "immediate results." While the turbidity standards recommended by Mr. Hazen, Mr. Whipple and Mr. Goetze may be satisfactory for very turbid applied water, in the opinion of the speaker, they are not as good as the simple tube for filtered water, which is, or ought to be, always practically free from appreciable turbidity.

The tube used for this purpose at Bremen is a practicable device which an ordinary filter attendant can easily handle. The color of the water in that depth is a very good indication of the operation of the filters. In London, the chemists, appointed by the Government to test the quality of the water supplied to the metropolis by the different water companies, used to publish a weekly report stating that the filtered water, as seen through a 2-ft. tube, was yellow, green or brown. These different shades indicate varying proportions of suspended matter in the water.

In Paris the speaker used a 3-ft. tube for the rapid and frequent examination of each filter, and a 15-ft. tube for examining, once a day, the general filtrate from the pure-water well. In one case he had to deal with a filter plant having a very great number of units (more than 2 000) divided in sixteen sectional collectors. When all the units were working normally, the water in the tubes, either small or large, did not obscure the light in the slightest degree, the blue sky appeared as blue and the white clouds as white as if no water had been in the tubes; but as soon as a single unit went wrong the water in the short tube lost its brilliancy and that in the long tube appeared slightly yellow. When several units were defective the color was more intense, and turned to green, and, as the defective units increased in number, the water became brown, the raw water, of course, obscured the light entirely and appeared black. As soon as all the defects were corrected the filtrate became again absolutely colorless. The speaker would recommend the use of a 2-ft. or 3-ft. tube for checking the daily work of each filter.

The author affirms that the "sand *per se*" is not a true filtering medium; that it is "the slimy coating (*Schlammdecke*) which is deposited upon and between the grains of the upper layer of sand" that does the work. He speaks of the "favorable interactions of bacteria and algæ," and of "organisms consuming and producing oxygen." He states, further, that "a filter bed filled with clean sand is not an ap-

Mr. Maignen. paratus which could be called a filter, * * * only by the so-called *Schlammdecke* is there formed the filter which is suitable to retain the bacteria;" and again, that the sand layer is used as a biological filter.

The speaker is of opinion that the author attributes too high a value to the *Schlammdecke*, or *Schmutzdecke*, or, in plain English, "mud blanket" and too little to the sand itself, and that the effects of the so-called biological action, so much dwelt upon during the last ten years, have been overrated.

Further, he believes that the surface of a sand bed is a hecatomb for the water bacteria, and not necessarily a breeding ground for them.

In open filters the water insects and infusoria may feed on the bacteria, fresh-water sponge and algæ, which grow by the favor of the light, act as a kind of preliminary filter, and may entangle some of the bacteria; but it is not likely that the bacteria themselves eat one another; they are retained like the rest of the suspended matter, and contribute physically to the formation of the complex substance which is called "mud."

In covered filters, where the sunlight does not penetrate, there is much less animal and vegetable growth, yet the speaker is not aware that the filtrate of covered beds is inferior to that of open beds.

The speaker calls attention to his observations on "ripening" filters,* in his discussion on "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey." There he showed that sand or granular-bed filters could be rendered "ripe" by filtering practically sterile water during a certain time, say one month. They became "ripe," that is, capable of giving an almost sterile filtrate without the formation of any kind of "mud blanket," and they continued to give perfect results for months afterward with applied water very rich in bacteria.

The author recommends that "the coherence of the bacterial mass beneath the removed layer must not be disturbed"; he advocates the removal of only the "most dirty layer" and not the whole of the "slimy coating." There are filter plants in this country in which all the dirty sand is not removed, and others where it is entirely removed; and, as far as the speaker knows, it is the latter filters which give the best effluent; therefore, he cannot agree with the author on this point.

The author acknowledges that a "ripe" filter may deliver a poor filtrate during floods. According to the biological theory, when a filter is old it is "ripest," and should, than, if the theory were strictly correct, do its best work when it is oldest, yet at such times, if the applied water is roily, the filtrate becomes poor, and, therefore, an explanation, outside of the biological theory, must be sought.

* *Transactions*, Am. Soc. C. E., Vol. L, p. 447.

Mr. Maignen.

The speaker ventures to suggest the following theory for the breakdown of "ripe" filters, when the applied water becomes bad. In the act of filtration, the water in its downward course gradually creates microscopical fissures, passages or channels, after the fashion of underground waters which flow long distances in fissures. As long as the applied water is comparatively clear there is no disturbance in these filtering channels, the particles of suspended matter are comparatively large and light, and are easily retained on the surface, but when road wash and finely divided clay are brought down by heavy rains a new factor intervenes, the fine particles of clay, microscopical stone detritus and other amorphous matters are carried with the water through the above-described channels, and it is believed that by their weight and number, as well as by their irregular form, they have a tendency to increase the erosive action of the flowing water and actually enlarge the channels through which they pass. This fact is particularly noticeable by the discoloration of the sand in some parts of the filters, and particularly along the walls and piers.

Something has been said about the unsatisfactory operation of sand filters in winter. May there not be some such erosive action produced by the cold water, which, of course, is not as fluid or filtrable as the warmer water of summer?

The author recommends that the water should be refiltered when the first filtrate is poor, particularly after refilling and in time of flood. By doing so he applies on a large scale what is done in the laboratory when precipitates are separated from fluids by filtration through filter paper. The first filtrate is usually cloudy because there are pores in the paper larger than others, when these become masked by a portion of the precipitate the liquid comes out clear, an artificial filtering membrane has been formed and the heterogeneous surface has been rendered homogeneous. This is essentially a physical process. The author's process differs from this only in the fact that, instead of passing the first filtrate through the original filter, he passes it through another filter of like character.

The author compares the action of slow sand filters to Nature's process, and says:

"In filters which are carefully provided with a sand layer of even grain, and through which the flow of water is regulated according to the best means known to the art, a process of cleaning (purification) takes place analogous to that which in Nature produces the highly praised spring water."

As a matter of fact, sand, in Nature, has not much to do with the purification of water. It is known that when a cesspool is within easy distance of a well, and when the soil in which both are located is made up of "sand of even grain" there is "infiltration," or slow filtration, of the poisonous matters from the cesspool into the well. The same kind of unsatisfactory result occurs with what is known as

Mr. Maignen. "surface springs," whether the surrounding soil is sandy or otherwise; whan the rain falls the so-called spring water becomes cloudy.

In Nature, the water found in sand-bearing strata is not dirty when it gets there originally. The water of Nature's springs generally comes from distant forest lands where the mossy growth acts as a preliminary filter, or it may come from slowly melting snow, in which case the loamy soil also acts as a preliminary filter. In any case, the mud does not get into the sand, hence it is that the so-called natural sand filters, which give up their water in the shape of springs or wells, never get clogged.

Many engineers have been tempted by the idea that the gravel soils which are on a level with the river banks could be converted into natural sand filters by being drained into so-called filtering galleries, but much disappointment has been met with by those bold enough to try. For a few years, perhaps, very fine water is thus obtained, but a time comes when the water originally stored in the sand strata is practically exhausted; the fresh water which flows from the river into the gravel carries with it mud which accumulates at the points of contact between the liquid and solid elements, and the mud itself blocks the "natural" filters as it blocks the embankments of canals or the surface of artificial sand filters. If any water then penetrates the gravel, it does so, not through a great number of small filtering passages, but through large fissures or "rat holes."

For instance, at Nancy, in France, filtering galleries were established in sandy soil alongside the River Meuse; for a time, plenty of water found its way into the galleries, and it was of very satisfactory quality, but, after a certain period, the mud clogged the sand nearest to the river, and the sandy soil surrounding the galleries became dry. The galleries themselves continued to give water, but it was unfiltered, it came direct from the river through large fissures, and caused considerable sickness in the town.

It should be remembered that the art of filtration is not limited to the passage of water through a porous body, it extends also, and we may say, above all, to the keeping of the filtering surface clean. The prize will be for those who will devise the best and most economical means of disposing of the mud.

So-called "natural" sand filters are not easy to clean, therefore they may be dismissed from consideration at present.

If it is desired that sand filters work as in Nature, care should be taken that the water sent on them be as free from suspended matter as it is in Nature. Sand makes a very good bacteriological filter, the bacteria do not find sustenance in it, and if the applied water, as stated by the author, is fairly good all the time, the filtrate is always well nigh perfect; therefore, it may be laid down as a principle that all water supplies intended for sand filtration should receive a preliminary treatment.

Mr. Maignen.

What is done at Bremen cannot be correctly called "preliminary" filtration and "final" filtration; it would be more accurate to call it "first" and "second" filtration.

The speed of filtration recommended by the author, namely 1 600 000 to 2 000 000 galls. per acre per day for the "first" filtration and 2 600 000 to 5 000 000 galls. for the "second" filtration, may be practicable in places where the consumption is from 20 to 30 galls. per head per day, but it would be altogether out of the question in this country, where the *per capita* requirements vary from 60 to 200 galls., on account of the enormous expense of first installation.

Downward filtration through sand, coarse or fine, slow or rapid, cannot, in the speaker's opinion, be recommended for "preliminary" filtration. It must always be an expensive operation because the voids between the grains of sand are necessarily small, and they become very quickly closed up, the quantity of sand necessary to retain a certain quantity of mud is very considerable, and the handling of the dirty sand, whether it be washed *in situ*, as in mechanical filters, or removed, as in slow sand filters, forcibly necessitates much power, labor and wash-water. Whatever qualities as a "final" system sand filtration may have, it cannot be considered an economical process of preliminary filtration.

Upward filtration through sand, also, cannot be thought of for preliminary filtration, for the same reason, that too much material has to be handled for a given quantity of mud, and also because the upward flow of water through sand transforms the filter bed into quicksands and surface springs.

A true system of economical preliminary filtration has been inaugurated quite recently in Philadelphia, at the Lower Roxborough filter plant. It will no doubt be brought to the attention of the Society in detail some day, but, on this occasion, it may be briefly described:

The filtration is upward; the materials used are, first, a layer of slag in pieces varying in size from 3 ins. to $\frac{3}{4}$ in., and second, a layer of sponge. There is practically no loss of head, the effluent rising within 1 or 2 ins. of the level of the influent, and the operation goes on for three months or more without any attention or labor of any kind. The slag is cleaned by downward, reverse flushing, and the sponges are washed in laundry machines.

There is an old saying in Germany to the effect that when dirty water has run over nine stones it becomes clear, alluding, no doubt, to the behaviour of wash-water or sewer-water in village brooklets. This is well illustrated in the Philadelphia preliminary filter, which has a bacterial efficiency varying from 80 to 95%, with a speed of filtration of 48 000 000 to 60 000 000 galls. per acre.

In this preliminary filter there is plenty of room for the mud, and

Mr. Maignen. the quantity of material to be handled, for a given quantity of mud, is reduced to a minimum, hence its economical operation.

The object of the Bremen system of intermittent double filtration is to insure at all times a good filtrate; the object of the preliminary filtration, as carried on in Philadelphia, ought to be, in the speaker's opinion, threefold:

First, to insure a good filtrate at all times;

Second, to reduce the cost of first installation by allowing the final filters to work at higher rates, say 6 000 000 galls. or more per acre per day, and

Third, to cut down the cost of operation of the "final" filters by reducing the number of sand-cleaning operations.

Mr. George W. Fuller. GEORGE W. FULLER, Assoc. M. Am. Soc. C. E.—This interesting paper makes it plain that the City of Bremen has a filter plant which is well built and well operated. That view is certainly confirmed by those who have had an opportunity to visit the works and examine the results of the many studies made by the author, and of which those presented in this paper are representative.

There is one feature, not mentioned by the author, which is of importance in recording the accomplishments of a filter plant which has been in service for a long term of years, and that is the effect which has been produced, upon the people who drink that water, with reference to the prevalence of water-borne diseases, such as typhoid fever. As the speaker remembers the statistics, the annual death rate from typhoid fever in the City of Bremen is only about ten per hundred thousand of population. That, it will be recalled, is less than one-third of the proportional number of deaths from this disease in the average American city, and about one-half of that in those cities in this country which are considered to be provided with very good water.

There are, of course, other factors besides the water supply which are related to the proposition of low death rates from typhoid fever, but it seems that, in connection with this paper, it is very desirable to bear in mind the actual accomplishment of the filters which is aimed at; that is, to give the people a water which is not only pleasing in its appearance, but one which is thoroughly safe to use for drinking purposes.

In the management of the Bremen filters, there is a feature which is worthy of considerable study by the water-works engineers of this country. Even with such devices as the by-passes mentioned by Mr. Hazen, where opportunities are available for getting into trouble, it is significant that those troubles have not come. Great influence, in the opinion of the speaker, ought to be exerted by engineers in this country toward bringing filter operations to a higher plane of excellence. While many filter plants in this country, both of the sand-filter and

Mr. George W. Fuller.

the mechanical-filter types, are well operated, there are many which are not so well operated. It is believed that this is a very important factor to be borne in mind, in connection with the development of water purification in America.

Why the Bremen filters do not produce a better effluent when for short periods a moderate turbidity appears in the river water, is a question which requires considerable study, and is difficult to answer.

With filters of this type, operated at several places in the United States, especially on the Ohio River and on the Mississippi River at New Orleans, they have been able, with a turbidity greater even than that encountered at Bremen, to produce a good filtered water for quite a number of days after muddy water appeared. Frequently, as many as ten days have gone by, with very turbid water going on the filters, and still the filtrate was satisfactory in appearance and excellent, bacteriologically.

These differences in experiences are doubtless due to differences in conditions which are difficult to gauge. How far the character of the organic matter which forms films upon the sand grains (of which so much is said in Germany, but which in this country is not considered so much a factor) may explain these particular results, it is hard to say. It seems to the speaker that the shallower sand layers, which they have used at Bremen and other places in Europe, may be a factor of some consequence.

Speaking generally of double filtration, it appears that there are many waters in this country where there may be opportunities for the advantageous application of such a method. Some of them are in connection with those waters which become turbid for short periods, but not sufficiently turbid to render necessary large investments for settling basins or coagulating basins.

Others refer to waters which have bad tastes and odors, due to vegetable growths, such as that which has been studied for many years at Springfield, Mass. The studies of the water of the Ludlow reservoir are along lines different from those which have been usually studied elsewhere. They refer to the removal of tastes and odors produced by *Anabæna*, a vegetable growth which seems to have oil sacs contained in it. Upon dying, this oil, which is very pungent and penetrating, is liberated. A small quantity of it will affect a large volume of water.

Double filtration is useful, in connection with such waters, in facilitating oxidation, and can produce a good effluent; whereas, with single filtration, the result at times is decidedly unsatisfactory.

In general, double filtration is something of which a great deal more will be heard in the future.

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PAPERS AND DISCUSSIONS.

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A DESIRABLE METHOD OF DREDGING CHANNELS THROUGH RIVER BARS.

Discussion.*

By Messrs. Rudolph Hering and W. W. Harts.

Mr. Hering.

Rudolph Hering, M. Am. Soc. C. E. (by letter).—The immense territory of Russia, with its comparatively small population per square mile combined with the existence of many large rivers, seems to favor a great development of river navigation in that country. During the last fifteen years Russian engineers have been giving this subject much attention. Large sums of money are being spent in regulating streams so as to secure at all seasons a sufficient waterway for barges and steamers. The long distances to be navigated, and the many smaller streams which it was desirable to bring into use as waterways, made it necessary to confine navigation to shallow-draft vessels, in the expectation that, later, when the growth of traffic demanded it, a greater depth of channel could be secured.

The present improvements, as well as those in other countries, have been made by permanent works and by dredging. The author refers only to the latter, and suggests what he calls "a desirable method of dredging channels through river bars," by giving to the channel to be cut a different shape from the usual one. In this he does not mention a fundamental proposition for all river improvements in the alluvial

* This discussion (of the paper by S. Maximoff, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for October, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to January 23d, 1904, will be published subsequently.

territory of which he speaks, namely, to retain carefully the original regimen after the improvement has been made; in other words, the equilibrium between moving and resisting forces. The opening of a channel across a bar in this situation, increasing both sectional area and velocity, must be balanced, if the channel is to remain open permanently, by the reduction of the sectional area corresponding to the new and greater velocity, where this is least expensive and where the waterway is required. Mr. Hering.

To hold the proposed channel permanently, it would therefore be necessary to build jetties or spurs from the banks, on either or both sides, thereby narrowing it sufficiently to balance the increased velocity.

With this condition, the writer believes the author's proposition will accomplish the desired purpose. This purpose is, first, to have the bottom of the new channel slope in the direction of the current, rather than to keep it level or sloping in the reverse direction. The material of the bar, if it is shifting sand, will undoubtedly be pushed along by the water more readily on a down- than on an up- grade, and thus the scour will be more effective. The second proposition is to make the dredged channel at the down-stream end narrower than at the up-stream end. This suggestion is also sound, because, if the narrowing corresponds to the deepening, the bottom velocity or scouring force in the newly dredged channel will not at first decrease at the lower end, as it would otherwise do, but it will rather increase and therefore help to scour until the permanent regimen is established.

Therefore, there seems to be the best of reasons why the author's general proposition is justified.

WILLIAM W. HARTS, M. Am. Soc. C. E. (by letter).—The writer has followed with much interest the data presented by the author, showing the very decided increase within recent years in vessels engaged in commerce in the interior of Russia. The comparison in tonnage, made in Table No. 1, with the merchant fleets of other countries is also somewhat of a surprise. The decided increase in appropriations during the last seventeen years, given in Table No. 6, shows that the needs of this commerce are realized and that measures are being taken to meet these new requirements. Mr. Harts.

The conditions of work are not fully explained, but the average cost of dredging per cubic yard seems low for the kind of dredge used. It appears that the dredging is done by what is ordinarily known as a "ladder" dredge, while one of the cuts shows the dredged material being pumped away by means of centrifugal pumps. In other cases referred to, the dredged material is handled in scows. It is understood that this form of dredge has been tried in this country and discarded as unsuitable to our conditions. They are still being used in Manila, as they are an inheritance, from the old Spanish gov-

Mr. Harts. ernment, received by the United States on the evacuation of the Philippine Islands, and not yet replaced. Their first cost is high. The large number of moving parts makes breakages and delays in repairs serious objections, while the enormous weight necessary to be moved while working and changing location makes this form inconvenient in operation. In first cost, therefore, in maintenance, and in operation, dredges of this class do not compare favorably with dredges of the dipper, grapple, and suction types used in this country.

The best methods of securing a useful increase of depth in rivers is being given much study in America, on account of the enormous value of our internal waterways. These vary in character from tidal rivers to mountain streams, including rivers like the Hudson in its lower reaches, and the Lower Columbia; rivers in alluvial basins, like the Ohio and Mississippi; steep mountain streams, like the Kentucky and Monongahela, while streams of nearly every character may be found, and many varieties call urgently for betterment.

Dredging is the layman's cure for all lack of depth. It is homœopathic in its application, in that it is symptomatic. It affords immediate relief at the point where the trouble is felt, but the causes producing the shoal places and the result (elsewhere) of the cure are not always considered sufficiently beforehand. In many rivers, dredging through a shoal by a deep cut of any useful size would lower the water on shoals in the upper reaches, so that this method of improvement would occasion more general injury than benefit in such streams. In other cases, where the conditions producing the shoal are not modified or corrected, the improved channel soon silts up again. It may be stated broadly, therefore, that each river must be studied in its entirety, to develop properly a successful plan of improvement, and each shoal of the river, likewise, must be examined and studied separately, as well as in its relation to the remainder of the stream.

The writer heartily agrees with the author in his statement:

"It is important to find such a shape for the channel to be cut as will not only prevent any filling up, but insure its maintenance and even its scouring and deepening."

He can scarcely agree, however, with the implied suggestion that such a shape can be found that is applicable to any but exceptional cases. The art of river engineering assists in locating dredged channels where it is probable that the maximum and most durable benefit will be secured in the shortest time at the minimum cost, but there are so many conditions to be examined, so many different problems to be solved, that it seems very doubtful whether the shape of channel suggested by the author would be of any particular advantage anywhere, except in special instances, to meet special conditions. In tidal rivers it usually appears that shoal water is found wherever the flood current

takes a different channel from the ebb current. Where these two currents cross or flow in the same channel, deeper water is usually encountered. In what direction should the funnel-shaped cut proposed by the author be pointed, in dredging such a shoal? Mr. Harts.

Again, shoals are found which are produced by easily discovered causes, as at the mouth of the Willamette River, where it enters the Columbia. These two rivers are in flood at different times, the Willamette at one season of the year, from heavy rains, and the Columbia at another season, from melting snow. When the Willamette is in flood, the Columbia is backed up, and a deposit of silt in the Columbia is noticed above the Willamette's mouth. When conditions are reversed, a similar shoal is found in the Willamette River. Would a funnel-shaped cut in either river accomplish anything more permanent than the usual dredged channel? It seems that the title of the paper is, perhaps, more comprehensive than was intended.

The writer's opinion of this paper is, that the statistics and data concerning the commerce of Russian rivers are of much value, as information of this class is usually hard to get, in convenient form for use, but that the method suggested for dredging river bars is desirable only in special places on special rivers.